THE PEDAGOGICAL SEMINARY AND

JOURNAL OF GENETIC PSYCHOLOGY

Child Behavior, Animal Behavior, and Comparative Psychology

EDITED BY

CARL MURCHISON

VOLUME 59

1 9 4 1

Published quarterly by The Journal Press
Provincetown, Massachusetts, U. S. A.

AUTHOR INDEX

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7.00 per volume
Single numbers $4.00

QUARTERLY
Two volumes per year

September, 1941
Volume 59, First Half

Founded by G. Stanley Hall in 1891

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Entered as second-class matter, August 3, 1897, at the post-office at Worcester, Mass., under the Act of March 3, 1879
Re-entered as second-class matter, May 11, 1937, at the post-office at Provincetown, Mass., under the Act of March 3, 1879

The Journal of Psychology

EDITED BY

Carl Murchison

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THE JOURNAL PRESS
2 Commercial Street
Provincetown, Massachusetts
U. S. A.

$7.00 per volume — Two volumes per year — September, 1941
Single numbers $4.00 — QUARTERLY — Volume 59, First Half

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(Manuscripts are printed in the order of final acceptance)

(over)

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The Journal of Genetic Psychology, 1941, 59, 3-26.

RELATION OF COMPREHENSION TO TECHNIQUE IN READING*

Department of Psychology, Royal Hungarian Francis Joseph University of Szeged

ERZSEBET I. BARANYAI

Investigations with reference to reading, as investigations in general, for a long time have suffered from an atomistic outlook. For example, the endeavor of Erdmann and Dodge, early and classic investigators of reading, though alluding sometimes to connection between the elements of the performance of reading, was to isolate them from each other without considering the performance in its entirety. Recent studies have a different point of departure, but still much ought to be done to describe the integral psychological situation which takes place during the reading. The present study attempts to be a contribution towards the finding of some facts by which the entire performance of reading may be characterized.

A. PROBLEM

When a text is being read, three mechanical processes—vision, recognition, and reproduction—take place and along with these also an intellectual process goes on. The product of the mechanical processes is the technique, that of the intellectual processes, comprehension. In the actual performance of reading, all these processes are combined and intertwined. Past studies have already shown a relation between them. Our question is a further one: exactly in what does this relation consist and in what way and to what extent does comprehension influence the technique?

B. PROCEDURE

For the purpose of examining the nature of relation between the different processes, situations had to be set up in which the different factors vary in their effectivity. Three texts were given to children to read. One was a popular tale, not known by them but presumably completely understood, this was a meaningful text. The

*Received in the Editorial Office on March 10, 1940

other was a fragment of a psychological treatise from which children understood words, word groups, and at best one or two clauses, this was a partly meaningful text. The third was a Latin text, entirely incomprehensible to the children, this was a meaningless text.[1]

Texts were mimeographed so that there was a sheet for every pupil with his or her name and class on it. The sheet was kept by the examiner to mark mistakes, time taken for reading, etc., while the children read from print (book or periodical). Efforts were made to keep conditions constant: reading took place only in the morning, during the regular school hours.

Pupils of the Practice School of the Teachers College of Szeged served as subjects for the investigation.[2] The investigation took place in 1931 and the whole experiment was repeated the following year. The average number of pupils in a class was 17. On the whole, 238 pupils were examined.

The first text contained 1000 syllables, the second 800, the third 4000. All results, however, had been computed on the basis of 1000 syllables, results of Text II being multiplied by 1.25 and those of Text III by 2.5.

By repeating the investigation the following year, we acquired a record of the development of comprehension with the same individual. This way, we had two sets of data. With one, the age is constant and the text which demands different degrees of comprehension, is variable; with the other, the text is constant and the age which yields different degrees of comprehension, is variable.

The individual accomplishment of the readers was then computed with the help of a formula, and such indices of the individual reading tabulated.

The formula was one used by Ranschburg (9, p. 20). This formula characterizes the performance from both sides, that is from the side of rate and that of accuracy. The formula is $Ls = J\frac{Tr}{T}$. To interpret the meaning of the letters:

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[1]This plan was set up in collaboration with Dr. Joseph Somogyi, Professor of the Teachers College of Szeged, who had asked me to carry out an experiment with the practical aim of introducing students to experimental work

[2]The school consists of four classes, pupils are 10-14 years of age. It is a kind of junior high school built upon the four years' course of the elementary school. As the aim of the school is more practical than that of the eight years' course Classical High School, Latin is not taught here

Ls = *Labor summus,* i.e., all work actually done. It means that not only the positive performance but also the negative performance is taken account of by way of including the mistakes which were corrected.

A = *Amplitudo,* i.e., scope of the performance. Equals the units correctly read plus half of the units incorrectly read but corrected, in percentual relation to all the possible units. For instance, if a pupil made 20 mistakes but corrected four of the 20, he will have a record of 18 mistakes, consequently 98.2 units out of the 100.[3]

Tr = *Treue,* i.e., truth of the performance

The latter factor is expressed by a detail formula $\frac{r}{r+f}$. The meaning of the r and f letters is the following:

r = *richtig,* i.e., right which means the number of correctly read (or corrected) syllables

f = *Fehler,* i.e., mistake which means the number of syllables that were neither correctly read nor corrected.

At last, the meaning of the T:

T = *Tempus,* i.e., time taken for the performance.

The formula then, giving also the details, is the following:

$$Ls = A \frac{\frac{r}{r-f}}{T}$$

Out of individual records, averages were computed in every class and these were used in filling out the formula. An example:

The average number of mistakes made in Class I and at Text I by the girls, in 1931, was 2.6; the average time taken for the reading of one syllable was 0.247 seconds; according to the formula:

$$Ls = 97.4\% \frac{\frac{97.4}{97.4-2.6}}{.247} = 97.4 \frac{.974}{.247} = 94.8676 \;.\; .247 = 384.0$$

$$\begin{array}{r} 2076 \\ 1007 \\ -196 \end{array}$$

The index of the accomplishment is then 384.0

[3]By unit, a syllable is meant.

Repetitions were also scored as mistakes on the ground that repetitions disadvantageously influence the technique of reading and so must be especially expressed in the index of the accomplishment. However, as repetitions are already included in the rate of reading, since they increase the time taken for reading, only 50 per cent of them were counted as mistakes.

C. Results

1. *Central Tendency*

a. Variation of accomplishment by texts. The indices should be read in a horizontal direction from left to right, considering records made on the first, then second and lastly third text (Table 1).

TABLE 1
Indices of Accomplishment by Texts

	Text I	Text II	Text III
	Boys		
Class I	301.7	262.0	129.7
" II	351.7	310.9	142.0
" III	367.2	319.3	135.1
" IV	381.0	329.6	139.0
	Girls		
Class I	370.5	277.8	135.3
" II	364.5	311.9	153.6
" III	415.5	384.9	175.2
" IV	364.0	357.5	157.0

It is clearly seen that in every case, without exception, the accomplishment is better at the first text than at the second, and better at the second than at the third. To explain this phenomenon, we have to consider the rôle of the mechanical as well as of the intellectual factors. The rôle of the mechanical factors consists of the optical stimulus that the letters represent, the acoustic images that the combination of letters evoke, and the motor innervations that end up in the utterances of the group of sounds. With the text of an unfamiliar language, these mechanical factors operate in their purity and are not helped by visual, acoustic, and motor images which are already possessed by memory. With the text of a familiar language, on the other hand, mechanical factors are conditioned which means that mechanical processes are helped by images drawn

from memory. The result is then that the identification of letter groups, along with the adequate motor innervations (utterance) is quicker and more accurate than in the case where mechanical factors are not helped by such images. If we should read a text of familiar words which however conveys no sense, the index of the accomplishment would be better than in case we read an equally senseless text also with unfamiliar words.

It is then the intellectual factor which brings differences in the records made at the three texts. The images drawn from memory and helping the mechanical factors, come from the meaning. By the meaning, the text organizes itself into parts (that is to say into complexes) and these complexes are far larger than units organized only by mechanical factors. We have phrases kept in our memory, and by seeing the first word of them in print we remember the rest of them so that the reading of the whole phrase is not even necessary. With the help of the meaning, recognition need not progress bit by bit by small units, but may take up complexes of a wider span and thus give a better and quicker result. We have seen that where the intellectual factor was fully at play (Text 1), the accomplishment was at its highest, where the intellectual factor only partly worked, the accomplishment was lower, and where no intellectual factor was working, but only mechanical factors, the accomplishment was at its lowest.

Such result has already been attained by various investigators. Wagner (10) found in a techistoscopic experiment of reading that out of the letters of current words, 13 were identified, while out of a meaningless group of letters, only 7.

Proceeding now to the specific facts, let us put together the data of boys and girls and of all the classes (Figure 1).

Looking at the figure, we find that the increase in accomplishment is greater when going from the third text to the second than when going from the second to the first. To explain this phenomenon, the intellectual factor has again to be remembered. The greatest difference in accomplishment is between the texts of which one is not understood at all, and the other, though only partly understood, is of the mother tongue of the children. The smaller difference, on the other hand, is between the texts which are both of the mother tongue, both understood—fully or partly. It seems that the degree of accomplishment is proportionate to the degree of comprehension.

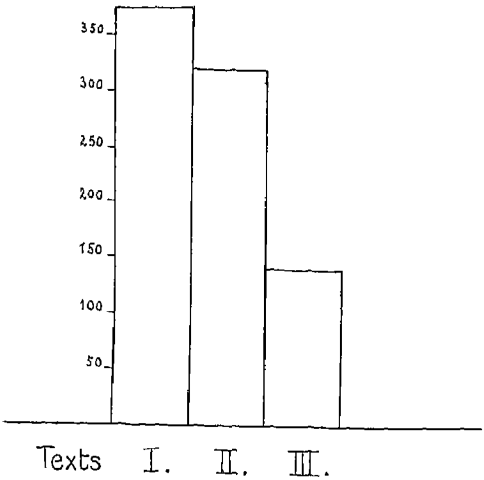

FIGURE 1

BAR-GRAPH SHOWING THE AVERAGE INDEX OF ACCOMPLISHMENT FOR THE THREE TEXTS

Ordinata: grades of the index of accomplishment.
Text I—364.5
Text II—319 2
Text III—145 8

In connection with the previous statement, the question arises: what exactly are the proportions in which comprehension raises the level of accomplishment? Let us bring the records made on the three texts in percentual relation with each other. The average index of accomplishment on the third text is 145.8. This we take as basis and consider it as 100 per cent. The average index of accomplishment on the first text is 364.5, the difference between the two is 218.7. We see now, how many per cent the difference represents, that is to say how many times the one per cent of the basical record, 145.8, can be found in the difference, 218.7 has to be divided by 1.458 = 150 per cent. The conclusion is then that comprehension raises the index of accomplishment by 150 per cent, in other words, accomplishment is one and a half times better when the text is completely understood as against the case where the text is absolutely not understood.

Should we want to compare our results with those given by

McKeen Cattell (7), we should have to figure out the indices of the accomplishment to rate only (Table 2).

TABLE 2
TIME TAKEN FOR THE READING OF ONE SYLLABLE

	Text I	Text II	Text III
	Boys		
Class I	0.315 seconds	0 348 seconds	0.609 seconds
" II	0.273 "	0.297 "	0.552 "
" III	0.257 "	0.285 "	0.565 "
" IV	0 250 "	0 279 "	0.537 "
	Girls		
Class I	0.256 seconds	0 331 seconds	0 613 seconds
" II	0.264 "	0 301 "	0.526 "
" III	0.233 "	0 250 "	0.483 "
" IV	0.266 "	0.267 "	0.492 "

If we put all data together and differentiate only in texts, the averages are:

Text I	*Text II*	*Text III*
2.64 seconds	2.94 seconds	5.47 seconds

We find that comprehension about doubles the rate of reading. This result is in a remarkable harmony with that given by McKeen Catell (7, p. 647) who says: "If we take words which do not form sentences and letters which do not form words, the time taken for reading is about doubled."

Hoffmann also found (5, p. 343) that in reading syllables, 50 per cent more letters are read than when reading simply consonants. Here again the effect of the complexes can be seen. Even a small complex like the syllable makes a difference. It is only natural that the greater the complex, the higher the rate and comprehension makes for greater complexes (because of connecting words) than a simple syllable can be.

The foregoing suggests the other part of the accomplishment, i.e., accuracy. The question is here, what are the consequences of comprehension with reference to accuracy (Table 3)?

If we put all data together and differentiate only in texts:

Text I	*Text II*	*Text III*
21.82	35 79	109.63

Again we compute the difference between the two extremes, the

TABLE 3
MISTAKES MADE ON TEXTS OF 1000 SYLLABLES

	Text I	Text II	Text III
		Boys	
Class I	25 15	44.75	111.62
" II	19.90	39.56	118.75
" III	28.30	45.30	123.50
" IV	23.00	41.87	132.87
		Girls	
Class I	27.75	40.31	93 75
" II	19.75	33.25	100.62
" III	15 60	19.43	75.37
" IV	15.15	21.87	120 62

difference is 87.81. We now take 109 63 as basis and ask, by how many per cents did accuracy improve when the intellectual factor was fully at work. One per cent of 109.63, that is to say 1.0963 is found in the difference, 87.81, 80.08 times. Comprehension then improves accuracy by approximately 80 per cent.

If comprehension improves rate by about 100 per cent and accuracy by about 80 per cent, the improvement of the whole accomplishment should be 180 per cent. Contrary to this, when examining the whole accomplishment with the help of the Ranschburg formula, we found only 150 per cent of improvement. The discrepancy must come from having used the formula which is a composite measure in which the two indices (rate and accuracy) stand in relation to one another, and this state of affairs must have slightly influenced the separate factors. However, the difference is only 30 per cent, which is relatively small.

Another feature of the question is: how great a share is taken by mechanical and separately by intellectual factors in the entire performance of reading; what exactly is the rôle of the pure mechanical factors and that of the intellectual? This can be answered by bringing the records of the first and third texts in percentual relation. It must be remembered that by the reading of the third text, only the pure mechanical factors have operated, whereas by the reading of the first, intellectual factors were fully at play. Taking the records made on the first text as basis, 364.5, we see how great a part of this is due to mechanical factors. The one per cent of the 364.5, 3.645, is found 40 times in the record of the third text, 145.8, where only mechanical factors operated. This result means

that 40 per cent of the whole performance is due to mechanical factors. Consequently in the performance of reading, intellectual and mechanical factors take part in the proportion of 60:40.

This result verifies the statement of Ehrenstein, the Ganzheit-psychologist, who says that performance of reading with educated adults is more than half built upon the contribution of central factors (memory and "Einstellung") (3, p. 75). The memory- and "Einstellung"-factors are exactly those which operate towards the obtaining of the meaning which we have called intellectual factors. Ehrenstein ascribes to the latter a power of building up more than half of the performance. In harmony with it, we find that the rôle of the intellectual factor is 60 per cent, that is to say more than half. Ehrenstein's statement is a fine theoretical appraisal which we are glad to verify on grounds of objective data.

b. Variation of accomplishment by advancement of age. We now turn to another situation where we consider pupils' accomplishment during two consecutive years. The purpose is to find out whether the mental development of pupils during one year, made any difference in their accomplishment and, if so, how does this come to expression. Again three texts will be considered, and records of two consecutive years will be shown (Table 4).[4]

TABLE 4

INDICES OF ACCOMPLISHMENT BY AGES

	Text I		Text II		Text III	
	1931	1932	1931	1932	1931	1932
			Boys			
Class I	315.4	368.4	263.9	314.5	131.2	144.2
" II	350.5	395.2	310.9	359.0	138.5	158.9
" III	386.4	386.4	325.6	359.6	138.5	141.9
			Girls			
Class I	384.0	416.7	302.4	366.7	148.0	171.2
" II	365.9	409.3	317.8	384.8	157.1	159.9
" III	409.4	454.9	383.3	452.4	170.7	181.6

The table shows the averages of accomplishment for classes and for texts. If we compare one year's index to that of the following year, we find in every instance with the exception of one that accomplishment improves with advancement of age. This increase

[4]Class IV is not included since they left school in the following year, and so data of rereading could not be secured

might equally be due to the development of mechanical (e.g., speech-motor capacity) and of intellectual factors, or else one of these has a larger share than the other in bringing about the change. To decide upon this, we have to see what the proportion of the yearly increase is in the different texts. For this purpose, we figured out the percentual increase in accomplishment for the second year (Table 5).

TABLE 5
PERCENTUAL INCREASE IN ACCOMPLISHMENT OF THE SECOND YEAR

	Text I	Text II	Text III
	Boys		
Class I of year 1931, in 1932	16.82%	19.23%	9.92%
" II " " " " "	12.73%	15.46%	14.67%
" III " " " " "	00.00%	10.42%	2.44%
	Girls		
Class I of year 1931, in 1932	8.51%	20.96%	13.56%
" II " " " " "	11.86%	21.07%	5.57%
" III " " " " "	11.12%	18.04%	6.37%

The figures mean the difference between the two years of accomplishment in terms of the per cent of the initial accomplishment. All the differences are plus, so the figures all mean increase.

All data put together and differentiating only in the three texts:

Text I	*Text II*	*Text III*
10.17%	17.53%	8.75%

Let us illustrate the situation with a figure (Figure 2). The figure reveals that the increase in the two texts with meaning, Text I and Text II, is greater than in that without meaning. If reading were purely a matter of the working of the mechanisms the increase in the text without meaning would be just as great as the increase in that with meaning because the development of mechanical factors is equally the same for both texts. It must therefore be supposed that intellectual factors entered into play and these latter made a greater development during the year than the mechanical factors. This greater development caused the increase in the accomplishment. From this, it follows that the yearly percentual increase in accomplishment is considerably enhanced when the intellectual factors have the chance of coming into play in the performance of reading. More specifically expressed: intellectual

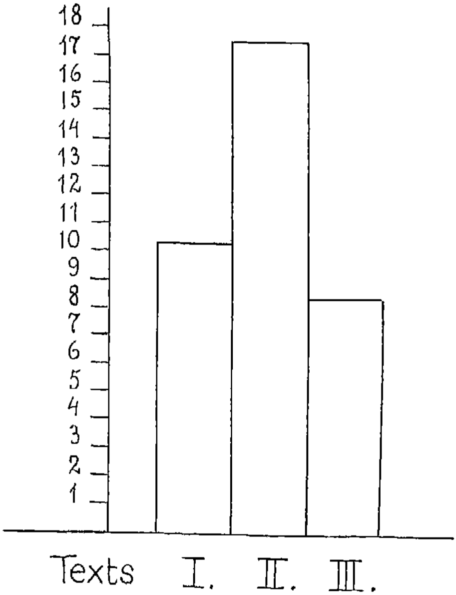

FIGURE 2

BAR-GRAPH SHOWING THE PERCENTUAL INCREASE IN THE ACCOMPLISHMENT DURING A YEAR IN ALL THREE TEXTS

Ordinata: percentual grades of increase of the accomplishment during a year.

Text I—10.17%
Text II—17.53%
Text III— 8 75%

development of one year raises the index of accomplishment to a greater extent than does the development of mechanics.

Examining the bar-graph further we find that the greatest percentual increase occurs in the second text with partial meaning. In trying to interpret this fact, we first note that the different texts made different demands upon comprehension. The first text was easy to understand, the second text was difficult to understand, and the third text was entirely impossible to understand, as mentioned before. When speaking of the meaning in connection with the text, the distinction must be observed which was made by Erdmann and Dodge relating to the connection of words (4, p. 169). Grasping the meaning means the discovering of connec-

tion between words. Erdmann and Dodge spoke of two kinds of connections: logical and grammatical. In the case of the first text, connections must only have been grammatical, because it could not be fully understood, only a grammatical structure could be felt. Observations concerning the carriage of the voice justify the distinction made by Erdmann and Dodge. The way pupils read revealed that they had discovered the grammatical connections without having understood the whole meaning of the text. Although discovering grammatical connections does not mean full comprehension, yet it has some intellectual character as against the absence of discovery of even grammatical connections. The question is: what is the cause of the greater increase in Text II versus Text I? The same argument as used before serves here as solution. If the improvement of the technique is only due to the growth of mechanical factors, the percentage of the increase would be the same for all three texts. However, the increase in Text II is much greater than that in Text I and Text III. On inquiring which of the texts has the greatest chance of improvement through comprehension we find that it is Text II. Comprehension of Text I could not considerably improve in the second year because the text had already been understood at the first reading; comprehension of Text III could not improve at all because it had been and remained completely incomprehensible. The greater percentage of increase in Text II must consequently be due to the improvement of comprehension.

As we have said before, there was no chance for improvement of accomplishment in Text I by intellectual factors because comprehension had already been complete at the first reading. This statement must be taken in a general sense and so applies to the majority of our groups of readers. But in the class there were probably a few pupils of a somewhat lower intelligence who still had the chance to profit by one year's mental development. This is what came to expression in the slight plus of the accomplishment of Text I as compared to Text III. It is interesting to note that Binet had a similar observation: when he experimented with a picture as to how many objects the children's memory would retain, he found that, when he repeated the experiment, although the intelligent children showed some improvement, the mediocre ones showed considerably more (1, pp. 263-64). He explains the phenomenon in that the intelligent children adapted themselves quickly in the first

instance while the mediocre ones were slower, therefore the progress of the latter is more noticed. He also remarks that the explanation seems somewhat paradoxical. However, it is true. For a parallel we replace intelligence by accomplishment and transpose Binet's observation to the reading situation. We find then that the best accomplishment does not improve at the same rate as that of the mediocre accomplishment. This is exactly what we have found in our investigation. We thus draw the conclusion that in the case where comprehension is perfect at the initial reading, the increase of the accomplishment during a certain period of mental development is less than in the case where initial comprehension is imperfect; in the case where comprehension is beyond the capacity of the reader, the increase of accomplishment, during a period of mental development, is less than in the case where comprehension is within the scope of his capacity.

In endeavoring to state the exact degree in which comprehension influences the technique, the percentage of improvement in the third text must be taken into consideration, because in the case of that text, the increase cannot be supposed to result from the development of mechanisms. The improvement in this text, 8.75 per cent, is evidently due to the development of mental factors. The operation of the intellectual factor is then zero. Adopting this basis, when examining the percentual increase in the other texts, we must take for granted that what is above 8.75 per cent in the other text, must mean the influence of comprehension. Thus we find that the improvement of the second text, 17.53 per cent, decidedly shows the influence of comprehension, and so also the first text, only to a much smaller extent. If we want to know, by how much comprehension raises accomplishment during a year of development, we must set the data into percentual relation with each other. The influence of comprehension is evidently expressed in the difference between 17.53 per cent and 8.75 per cent,—this is 8.78 per cent. We take the records of Text III, 8.75 per cent, as basis and see how much of its one per cent goes in the difference between records of the second and third texts, that is divide 8.78 per cent by .0875 per cent. The result is 100.34 per cent. This means that the increase of accomplishment in the second text is a hundred per cent greater than the increase in the third text during a year. In other words: in the case where comprehension is working, the increase in the accomplishment,

from one year to another is twice as much as it would have been, had only mechanical factors been operating. We may conclude: comprehension raises accomplishment in such a way that during one year between the ages of 10-14 years, the increase of accomplishment will be doubled.

2. *Variability*

a. Variation of accomplishment by texts. We now have to examine whether the variability of the performance brings any consequence as to our problem. Variability will be studied in two respects, one will be the different texts, the other the phases of mental development. We treat the two parts of accomplishment, viz., rate and accuracy, separately. The measure of variability is the standard deviation indicated by the sigma.

We have to consider first what the standard deviation means. It is a measure of the spread of the distribution. What makes the spread long? When problems can be solved by most of the people of the group who are given the test, in short when the test is easy, the variation will be small; on the contrary, when the test is difficult, the variation will be large. The cause is that the test challenges the ability in varied degrees. In the case of a certain test, some people are able to comply with the challenge, others could even comply with a greater challenge, while there are a few who cannot manage it at all. In other words, in a group there are people whose ability is about average, and others whose ability is above and below average. In case the test consists of several problems, there may be some which will be solved by those who are below average, more will be solved by those who are about average, and most by those who are above average. If most problems can be solved even by those who are below average, the variation will not be large. If, on the other hand, only the few above the average can solve all or most of all the problems, the variation will be large. The criterion of the variation is the difficulty of the test. Difficulty makes the spread long.

Grouping the indices of accomplishment by texts and observing the sigmas of the rate only, we get the following data (Table 6).

If we put all data together and differentiate only in the three texts:

Text I	*Text II*	*Text III*
2.31	3.01	2.16

TABLE 6
SIGMAS OF RATE IN THE THREE TEXTS

	Text I	Text II	Text III
	Boys		
Class I	2 52	3.31	1.80
" II	1.98	3.42	2.29
" III	2.01	2 35	0.80
" IV	3.44	4.52	2.45
	Girls		
Class I	3.03	3 51	2.52
" II	1 72	2.28	1 98
" III	2 09	2.00	2 01
" IV	1.71	2.74	3.44

We note that the average of sigmas of Text I and Text III are close together, while the average of sigmas of Text II is considerably higher. The same situation is found here as before. We saw then that the improvement of the accomplishment from one year to the other is much more considerable in Text II than in Text I, and Text III. We interpreted this by pointing out the rôle of comprehension with regard to Text II. The interpretation here must be based upon the same motives. The text which shows the largest of sigmas, must represent the greatest difficulty. That is Text II. How is it possible that Text II represented the greatest difficulty when there was Text III of a language entirely incomprehensible, therefore the most difficult of all? Here is just where the point lies. From the point of view of technique, Text III might have been the most difficult, but from the point of view of comprehension, it represented neither more nor less difficulty, for it was entirely beyond the pupils' grasp. Out of the two texts with meaning, certainly Text II was the more difficult and this greater difficulty comes to expression in the greater sigma of Text II. The greater difficulty refers to comprehension because otherwise Text III would have had the greatest sigma. The fact that the greatest variation is shown by Text II, which challenges comprehension most, speaks for the thesis that the factor which differentiates the rate the most, is the intellectual factor. The differentiation of the rate is thus bound up with the difficulty in comprehension. Hoffmann's results corroborate this conclusion, saying: "The intelligent and the dull children deviated more from the arithmetical mean when reading familiar words than

when reading merely consonants" (5, p. 368). We may then state the fact that with respect to rate, the intellectual factor differentiates accomplishment to a greater extent than does the mechanical factor. The greater the challenge which a text with meaning makes on comprehension, the greater the variability must be in the rate of accomplishment.

Let us now group the sigmas of the variation in accuracy by different texts (Table 7). If we put all data together and differentiate only in the three texts:

TABLE 7
SIGMAS OF ACCURACY IN THE THREE TEXTS

	Text I	Text II	Text III
	Boys		
Class I	3.34	4.44	8.90
" II	1.41	4.57	9.42
" III	2.52	2.97	12.18
" IV	1.91	4.04	10.90
	Girls		
Class I	2.22	3.23	8.08
" II	1.76	2.19	9.21
" III	1.59	1.73	5.87
" IV	1.48	1.97	9.11

Text I	*Text II*	*Text III*
2.11	3.14	9.20

We immediately notice that there is an unusually great difference between the sigmas of the first, second, and third texts. The high sigma of Text III, according to the theory about the relation between difference and variation means, that from the point of view of accuracy, Text III represents the greatest difficulty. We have seen before that from the point of view of rate, the greatest difficulty is represented by Text II. The situation makes a discrimination of difficulties necessary and that has already been made in the previous paragraph. The variation in rate is largely due to the intellectual, that in accuracy to mechanical difficulty. The situation is sufficiently interesting to be analyzed more minutely. Looking at the data, we find that the variation in rate is highest in Text II, because the accomplishment is uniformly lower in the third text and uniformly higher in the first. Evidently, as to Texts I and III, there is no

room for much variation, only Text II provides for it because those people who understand less, read slower, whereas with Text I and III, either all the pupils understand or none at all, consequently they all (or nearly all) read quicker or read slower. We have already thrown some light on this phenomenon by showing comprehension as a differentiating factor. If it is true that comprehension is a differentiating factor with regard to rate, why does it not differentiate accuracy as well? The explanation must take up a purely quantitative aspect. The spread of the indices of rate is naturally much smaller than that of accuracy, because it is in the nature of reading that it cannot be stretched out over an unlimited space of time, whereas with regard to accuracy, there is a possibility of making a mistake in every syllable. Though this is not an unlimited space since the number of syllables is limited, yet when it comes to the question of a thousand units, the opportunity for making mistakes is almost unlimited. Just because comprehension is absent from the performance, more mistakes are made and the making of more mistakes has almost an unlimited chance. Hence the large variation. Because comprehension is—at least to a certain extent—present in the performance in reading Text I, less mistakes are generally made and the smaller number of mistakes do not have so large a spread as the larger number of mistakes. In the foregoing we have said that the intellectual factor varies more the rate of accomplishment, now we may add on the other hand that accuracy is more varied by the mechanical factors. In its practical application, this thesis means that when testing ability in reading, if a text with meaning is given, the rate, if one without meaning, the accuracy should be measured. Another aspect of the practical application: there used to be the notion in schools that children must not read fast because in that case they did not understand what they have read; this notion is much mistaken, some children read quickly and yet they understand, or more correctly expressed they read quickly because they understand. As the rate is characteristic for a text with meaning, it is also an indication for the degree of comprehension.

As comprehension is something in which intelligence manifests itself, it is evident that if rate is an index for comprehension, it is also indicative for intelligence (in the case of a text with meaning). This finding is in harmony with a statement of Hoffmann's who says: ". . . the reading of a text with meaning is a better measure

for intelligence than meaningless material" (5, p. 369). He refers to rate which was measured by him.

Naturally these results do not mean that comprehension does not influence accuracy, just the opposite was shown before. Just because the influence of comprehension on accuracy is so tremendous, does the text with meaning show such a wide variation. But the cause of this variation is just the lack of comprehension, whereas the presence of comprehension comes best to expression in the variation of the rate of a text with meaning. We thus have then the situation before us that while from the point of view of central tendency, rate and accuracy are correlated, from the point of view of variability, they diverge, rate making more variation in a text with meaning and accuracy in a text without meaning.

b. Variation of accomplishment by the advancement of age. Let us now study variation as shown by the accomplishment of two consecutive years (Table 8). If we put all data together and differentiate only in texts and years:

TABLE 8

SIGMAS OF THE RATE OF READING

	Text I		Text II		Text III	
	1931	1932	1931	1932	1931	1932
Boys						
Class I	2.57	2.30	3.32	3.03	1.59	2.28
" II	1.95	2.17	3.42	3.48	2.25	2.23
" III	1.88	1.66	2.21	1.76	1.84	1.41
Girls						
Class I	3.14	2.57	3.39	4.24	2.77	3.74
" II	1.58	1.80	2.40	1.81	2.44	2.21
" III	2.28	1.67	2.32	2.29	1.86	2.87

Text I		*Text II*		*Text III*	
1931	1932	1931	1932	1931	1932
2.23	2.02	2.84	2.76	2.12	2.45

If in all cases, from one year to the other, the sigma for groups had decreased, we should say that the difficulty of the reading of the text became smaller in the second year than it was in the first. As a matter of fact, the sigma really decreased at the texts with meaning while it did not decrease but even increased at the text without meaning. The decrease of the sigma at the texts with

meaning indicates a mental development between the years 10-14 which makes less difficulty for the individuals and less variation for the group. Thus individual records come near to each other and the performance tends to become uniform. Similar phenomena were observed by Ebbinghaus who, summing up his findings in connection with the combination method, says: "The performance of the three thirds of the class differ from each other mostly in the lower grades and when advancing to further classes always become more like each other" (2, p. 431).

We cannot account for the fact that the sigma increases at Text II, but enough for us that it does not decrease, i.e., the difficulty does not get any less. From this, we may conclude that the mechanics of reading had come to a standstill somewhere between the ages of 10-14, whereas intellectual powers still improve the accomplishment of those who have not so far come up to the level of the others. Hence the less variation in the second year at the text with meaning. The two plateaus, that of the mechanical factors and that of intellectual factors are evidently not coincidal.

D. Conclusions and Theoretical Interpretation

By way of summary, we repeat the conclusions at which we arrived during the working up of the data.

1. The degree of accomplishment is proportionate to the degree of comprehension.
2. Accomplishment is improved by one and a half times when the text is completely understood versus the case where the text is completely not understood.
3. Comprehension approximately doubles the rate of reading.
4. Comprehension improves accuracy by approximately 80 per cent.
5. In the performance of reading, intellectual and mechanical factors take part in the proportion of 60:40.
6. The yearly percentual increase in accomplishment is considerably enhanced when the intellectual factors have the chance of coming into play in the performance of reading. Intellectual development of one year's span raises the index of accomplishment to a greater extent than does the development of mechanics.
7. In the case where comprehension is perfect at the initial reading, the increase of accomplishment during a certain period of

mental development is less than in the case where initial comprehension is imperfect; in the case where comprehension is beyond the capacity of the reader, the increase of accomplishment, during a period of mental development, is less than in the case where comprehension is in the scope of his capacity.

8. Comprehension raises accomplishment in such a way that during one year between the ages of 10-14 years, the increase of accomplishment will be doubled.

9. With respect to rate, the intellectual factor differentiates accomplishment to a greater extent than does the mechanical factor. The greater the challenge that a text-with-meaning makes on comprehension, the greater the variability must be in the rate of accomplishment.

10. With respect to accuracy, the mechanical factor differentiates accomplishment to a greater extent than does the intellectual factor.

11. The development of mechanical factors reaches their plateau somewhere between the ages of 10-14. After that, it is only the intellectual factors which may improve accomplishment in reading.

Let us now see to what theory of the performance of reading do our data and conclusions lead.

The three phases of reading (to be separated only in theory) are vision, recognition, and reproduction. All elements, viz., optical, acoustic, and motoric elements, beside the intellectual element, take part in the process of reading. Recognition is not only a matter of optical nature, nor is reproduction that of a motoric nature, as the old notion used to hold but rather all the elements are present at every phase of the reading.

Let us begin with vision which we differentiate from recognition. Current notion used to hold that stimulus is offered by the letters and the reader's activity begins with recognition. It seems to us that the activity begins sooner. Müller-Freienfels says that it is the subjective attitude which formulates the complexes in reading and not the objective coherences. In these terms, the complex is a unit of impression. For instance, he says, the four letters of the word "name" build a complex, but it will be different if our motoric attitude is that we read from right to left. In this case, the complex will be "eman" (8, Vol. II. p. 36). The impression of the word "name" and that of "eman" are different, which is as much as to

say that the stimuli of the two words are different. We have to conclude then that subjective attitude (Muller-Freienfels says "Einstellung") influences the stimulus. In the example mentioned by Muller-Freienfels, we have a motoric attitude. But attitudes may be also of a different type. During the reading, we expect to find certain words which follow from the meaning and thus we have an intellectual attitude. When we expect to see a word, we see it, even if it is not there. It is a well known type of mistake to read a word which is not correct, nevertheless suits the meaning quite well. It is the intellectual attitude which has a central part in the stimulus. And just because it is the intellectual attitude, all sorts of elements play in the process, the intellectual attitude being the one which embraces and holds them all together, optical, acoustic, and motor elements alike. Let us picture the process of reading Suppose we are reading the beginning of a sentence. We get some indications as to the sense of the sentence. This vague feeling may perhaps be embodied in an acoustic complex which would run on and evoke or create suitable complexes which translate themselves into optical stimuli. Similar process may go on using optical or even motor complexes. As can be seen from this, all elements may play in the process of vision. This comes from the intellectual part which is capable of integrating all sorts of elements into the one and same mechanism. Because the older investigators did not look upon comprehension as a central factor of performance, they exclusively ascribed an optical nature to the stimulus.

Similar conclusions may be arrived at if we look into another phase of reading, i.e., recognition. This process consists of the identification of complexes. A complex in this case is a unit of recognition, the extent of which is not fixed. A complex may have a large scope in which other and smaller complexes may take part. The richer the complex is, the easier it is to identify the parts, i.e., the smaller complexes which are contained. Out of the factors which operate at reading, it is the intellectual factor which is capable of building up such rich complexes When reading a text which we understand, there continuously emerge optical, acoustic, and motor images which help to evoke a complex by means of the meaning. Comprehension of one part of the complex may be embodied in an optical complex which would be completed or developed on grounds of the meaning and identified with the optical images which are

represented by the texts. On the other hand, comprehension may be embodied in an acoustic complex which, like the optical one, tends to be completed or developed, again on grounds of the meaning. This complex transforms into an optical complex so that it can be identified with the complex which is represented by the text. Similar processes may occur with reference to motor complexes. Consequently, at the phase of recognition, we again find that all elements are at play. The richness of the complex comes—as in the first case—from comprehension being the central factor. In the older descriptions of the process, we mostly find the optical element as the complex-building factor. Erdmann and Dodge, in arguing for the significance of configurational form in recognition besides the outstanding letters, only take up the optical element of recognition. They say: "The general clearness of recognition of words of more than 6-7 letters guarantees that the indirectly seen letters which, when isolated are only indistinctly perceived, become distinct from the rougher complex through apperceptive completion" (4, 182). Although they say in the introduction of their book that the three processes, viz., optical perception, reproduction of sound-symbols, and reproduction of meaning are intertwined and only isolated by abstraction, yet they recognize only optical elements in recognition, as they speak only of "writing-image" (*"Schriftbild"*) which emerges through the completion of letters indirectly seen. Although Wagner mentions the "sound-image" (*"Klangbild"*), Kirste, many years later, seems to go back to the monopoly of the optical image (6). Observation also speaks for the acoustic image taking part in recognition. We have often observed in the case of rather poor readers that they were first trying to sound the word in a low voice several times thus giving the impression that this activity was part of recognition. Some theoretical proofs also speak for the thesis. Let us examine where the images which are connected with the meaning are more likely to come from. It is evident that in general we speak more than we read. Consequently it might be supposed that more images of complexes are left behind by the spoken language than by the written one. The images of the spoken languages would naturally be of an acoustic character, whereas images of the written one of an optical character. When it comes to the completion of perception or to the creation of suitable complexes, and when these appeal to the meaning for help, there

is more chance for acoustic images to emerge than for optical, simply because acoustic images are more numerous. In the same way the presence of the motor element can be admitted if we consider that the sense is put into motoric complexes because generally we speak more than we read. Both acoustic and motor complexes are then transformed into optical complexes for the sake of identification.

Reproduction, the last phase of the process, may be an inner process (with silent reading) or an outer process (loud reading). In both cases (since silent reading is but an inner speech) the optical images which appear in connection with the letters, naturally must be translated into motor innervations. However, some other elements act as well. When I see a text and understand it, an acoustic image may emerge which, on grounds of the meaning, would be developed and only then would the complex be transferred in the domain of motor innervations. Thus we find that even in motor innervations, all the other elements also take part. The power behind them all is the intellectual factor which integrates the various elements.

From all this it follows that the three phases are not consecutive processes, one succeeding the other but rather simultaneous ones, one overlapping the other. New stimuli already make their debut while one is still busy with reproduction, and recognition goes still on while utterance takes place.

Let us now take the case of the text without meaning and see how the matter stands with it. The intellectual factor, consequently the whole intellectual process, is cast out from the reading of the text without meaning. Therefore the mechanism is impoverished and it loses many of the complexes which would come from the meaning. Let us take one of the factors for example, that of recognition. Stimuli in this case are represented purely by optical complexes. These do not develop or become complete because no intellectual images would help them in this. Nor would they transform into any other kind of complexes because there is no meaning which would work upon their extension Complexes would remain small and poor. Other phases would show similar conditions. It is just this poverty of the process which makes us understand why the earlier investigators, who mostly worked with meaningless material, interpreted reading as a narrow and poor activity. Here we see what a difference it makes if, in the interpretation of the reading process, the intellectual factor is placed in the centre.

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Horthy-kollegium
Szeged, Hungary

The Journal of Genetic Psychology, 1941, **59**, 27-40

THE TERMAN-MILES "*M-F*" TEST AND THE PRISON CLASSIFICATION PROGRAM*

Indiana State Prison

Edward L. Walker

The object of the present investigation was manifold. The prime purpose was to determine the possible value of the Terman-Miles *Attitude-Interest Analysis Test*, a test of "masculinity-femininity," in prison classification work (1). It seemed possible from reports made by the authors that the instrument might be useful in the detection of homosexuals or insipient homosexuals among adult males. It was hoped that the validity of the test in this respect might be determined.

In conjunction with this problem it also seemed possible that the correlation of "*M-F*" scores with information readily available in the prison files; i.e., mental ages, type of crime committed, total amount of time served, and prison disciplinary records might reveal additional, desirable information.

The Terman-Miles test, according to its authors, is an attempt to obtain an objective measure of masculinity and femininity. It consists of seven sub-tests, each of which is composed of a number of multiple choice or true-false items. Each possible answer has been assigned a masculine, feminine, or neutral value and thus marked "plus 1," "minus 1," or "zero." A plus score has been designated as a masculine response, a minus score as a feminine response, and a zero score as a response which is neither masculine nor feminine. The algebraic sum of the scores of the sub-tests indicates whether the responses made by an individual subject are predominately masculine, predominately feminine, and to what degree.

When the present investigation was conceived, it was thought possible that such an objective analysis of this personality trait might be useful in the prison classification program in determining the degree of custody and the type of housing, pointing out disciplinary problems and suggesting therapeutic measures.

*Accepted for publication by Edmund S. Conklin of the Editorial Board, and received in the Editorial Office on March 12, 1940.

Specifically, it was hoped that a comparison of "masculinity-femininity" scores with known behavior might result in an objective segregation of those inmates who might be homosexuals or who might become homosexuals because of enforced celibacy, or might point out those who might become prison disciplinary problems because of supposed masculine aggressiveness. In addition to these problems it was thought advisable to correlate test performance with intelligence, the total time the individual has served in prisons, and the type of crime for which the man was sentenced, in an effort to determine what effect these three factors might have upon the score.

The first step was to present the test routinely to a number of "Fish" (men who had not as yet completed the customary thirty-day quarantine period imposed upon all new admissions).

At the outset one major difficulty presented itself. Fewer than 50 per cent of the men could be induced to complete the test. Subsequent investigation disclosed that most of those who failed had scores on the Morgan *Mental Test* which indicated that they functioned on an inferior, borderline, or feebleminded level. As a consequence, an arbitrarily determined level was set below which the test was not presented. Actually the limit set was a mental age of 12.4, and only those men making scores above this figure were selected. This limitation reduced the number of uncompleted booklets to about 15 per cent of the men tested. This group contained about 50 men whose institution packet indicated involvement in sex deviations of any kind. Approximately 200 others were selected at random from the 2,500 remaining men in the prison.

Soon after the testing program was well under way, the author began collecting factual data on each of the men tested. Evidence of homosexuality came from the following four sources: (*a*) the crime for which the inmate was sentenced in the present instance; (*b*) previous crimes for which the inmate has been sentenced; (*c*) statements made by the trial judge and prosecutor in regard to the present offense; and (*d*) reports of institution officers and professional workers. No other source of information regarding the behavior of the man was deemed reliable enough to class him as a positive case of homosexuality. Thus each man was designated as a positive or negative case.

The mental age was taken from the results of the Morgan *Mental*

Test which is the only instrument which has been presented to the entire prison population.

The type of offense was the legal title for the particular conviction for which the subject was serving his instant sentence. This information was taken from the commitment papers.

The previous criminal record and thus the total time each inmate has served in all institutions was computed from the records of the Federal Bureau of Investigation.

The number of inside rule infractions represents the number of times the man had been remanded to the office of the deputy warden for disposition when he had broken an institution regulation. This information was taken from the records of the deputy warden on file in the warden's office (Table 1).

TABLE 1

DISTRIBUTION OF THE SCORES ON THE TERMAN-MILES ATTITUDE-INTEREST ANALYSIS TEST, FORM *A*

Intv. No.	Class Intv.	Frequency	
(8)	106/120	o	x—Positive Cases
(7)	91/105	xoooooo	o—Negative Cases
(6)	76/ 90	xoooooooooo	
(5)	61/ 75	xxooooooooooooooo	
(4)	46/ 60	ooooooooooooooooooooooooo	
(3)	31/ 45	xxxxxooooooooooooooooooooooooooooooooo	
(2)	16/ 30	xxooooooooooooooooooooooooooooooo	
(1)	1/ 15	xooooooooooooooooooooooooooo	
(—1)	—14/ 0	xxxoooooooooooooooooooooooooooo	
(—2)	—29/—15	xooooooooooooooooooooooo	
(—3)	—44/—30	xoooooooooooooooo	
(—4)	—59/—45	xxooooo	Number — 246
(—5)	—74/—60	ooooo	Mean — 17.7
(—6)	—89/—75	x	Sigma (Score) — 42.5
(—7)	—104/—90	o	Sigma (Intv.) — 2.8
		5 10 15 20 25 30 35 40	

Table shows the distribution of the "*M-F*" scores of the Terman-Miles *Masculinity-Femininity* test, indicating the positive and negative cases. The interval numbers in Column 1 will be used throughout this paper in reference to distributions of these scores, and Standard Deviations are given in terms of both score points and number of intervals.

Of the 50 men whose institution packet indicated involvement in sex deviations, 20 were designated as positive cases of homosexuality. The placement of these men in the total distribution of the "*M-F*" scores may be seen in Table 1.

Let us consider each of the positive cases in turn. The subject who made the most extreme score toward the feminine end of distribution (Intv. No. —6) has a community record as a confirmed sodomist (the term used legally to cover all forms of homosexuality), was sentenced to the institution for sodomy and has a record as an institution sodomist. However, the one subject (Intv. No. —7) who had the most feminine score of all those tested was incarcerated for rape upon a minor child.

One of the two positive cases in the fourth feminine interval, (Intv. No. —4) is a known institution sodomist of the passive type. The other gives no real evidence of homosexuality but was included because of pictorial evidence of heterosexual fellatio.

The next positive case (Intv. No. —3) was a modern Fagin who conducted a group of teen-aged boys in petty theft in Hammond, Indiana, and there was a considerable indication of "69" activities among most of the members of the group. The inmate is a late middle-aged man, and falls into the passive classification.

The next class interval (Intv. No. —2) contains one positive case, a man in his twelfth year of incarceration for murder. The evidence in this case consists of a notation that nine years before this study was carried out he was punished for committing sodomy with a cellmate. There was no indication whether he was the "wolf" (aggressive member) or the "punk" (passive member).

In the next class interval there are three positive cases. In one case the evidence is institutional punishment for sodomy which is included in a behavioral pattern of aggressiveness which indicates almost beyond doubt that he is a "wolf." Another is incarcerated on a charge of sodomy whose institutional and criminal records also lead one to believe that he is the aggressive member. The last of the trio is "doing time" for killing a man over improper advances, although the information available does not clearly indicate whether the advances were made by the inmate or the "victim."

The one positive case in the first plus interval is in exactly the same category and was involved in the same offense as a case previously mentioned in which there was pictorial evidence of heterosexual fellatio. In the second plus interval there are two cases. One is here on a forgery charge but the prosecutor states that he could have as well been sent for sodomy. The other is a man whose behavior pattern outside the institution oscillates between

being kept by women and homosexuals and whose crimes have consisted of snatching women's purses and apparel, which has been interpreted by the prison psychiatrist as a homosexual fetish.

The next interval toward the plus end of the distribution includes five positive cases. The first of these was admitted because of his confession of fellatio with a young girl. The second is a known institution "punk" or passive homosexual. His score of plus 36 gives no indication of the practice. The third is a confirmed passive practicer of fellatio which he began in the army eight years before. His score of plus 40 is roughly more masculine than 65 per cent of the total number of cases. The fourth was convicted of sodomy with young boys with no information as to the form or rôle he played. The fifth is a youngster in the fourth year of a life term for murder and was punished for committing sodomy in the institution.

The last four positive cases in intervals five, six, and seven are as follows. The first of these was convicted of rape out of a number of charges which were lodged against him at the time of his arrest. Sodomy was among those mentioned and filed, but rape carried a longer sentence and was thus imposed. The second is an aggressive individual serving a 25 year term. His record in the institution indicates sodomy, probably in the rôle of "wolf." The

TABLE 2

DISTRIBUTION OF SCORES ON MORGAN TEST*

MA	Frequency		*F*
Ab-N	000000		6
19.0	000000	Number — 240	6
18.4	0000	Average — 15.11	4
17.9	00000	Sigma — 1.65	5
17.3	00000000000		11
16.8	00000000000000000000		20
16.2	00000000000000000		17
15.7	0000000000000000000000000		25
15.1	0000000000000000000000000		25
14.6	00000000000000000000000000000		29
14.0	0000000000000000000000000000		28
13.5	00000000000000000000000000000000000		35
12.9	00000000000000000000000000000		29

*According to unpublished data compiled by Kenneth Brown of Indiana University, this distribution represents only 34.6 per cent of the prison population. The whole distribution of 2,243 *MA*'s is skewed to the high end.

Table shows the distribution of Morgan Mental Test scores which were used in correlating *M-F* scores.

third was included because he was charged with sodomy when he was supposed to have forced a girl to perform fellatio upon him. The fourth with a score of plus 91 is a murderer serving life and is a passive homosexual practicing fellatio in the prison.

Table 2 presents the distribution of the mental ages of the inmates tested. A Pearson r correlation coefficient of $.22 \pm .03$ was obtained between mental ages and "*M-F*" scores.

Table 3 gives the distribution of the total number of months each

TABLE 3

DISTRIBUTION OF TOTAL MONTHS SERVED

Months	Frequency		F
1- 10	ooooooooooooooooooooooooooooooooooooooooooo		43
11- 20	ooooooooooooooooooo		19
21- 30	oooooooooooooooooooooooooooooo		30
31- 40	oooooooooooooooo		16
41- 50	ooooooooooooooo		15
51- 60	oooooooooooo		12
61- 70	oooooooooooooooooooooo		22
71- 80	ooooooooooo		11
81- 90	oooooooooooo	Number — 248	12
91-100	ooooooooooooo	Average — 57.3	13
101-110	oooooooo	Sigma — 42.0	8
111-120	ooooooooooooooooo		17
121-UP	oooooooooooooooooooooooooooooo		30

Distribution of the total time in terms of months each man has spent in any penal institution. Data used in determining correlation between length of incarceration and "*M-F*" scores.

of the 248 individuals have served in all prisons. The Pearson r correlation coefficient between "*M-F*" scores and the total months of incarceration obtained in this study is $.18 \pm .035$.

Table 4 gives the distributions of "*M-F*" scores as separated by an arbitrary division of crimes. It is to be noted that there is a progressive decrease in the "*M-F*" score toward the feminine end in the order in which the distributions were arranged.

Each classification contains several legal offenses. Robbery also includes Robbery while armed, Bank Robbery, Attempted Robbery, and Auto Banditry. Larceny includes Grand Larceny, Petit Larceny, 1st and 2nd degree Burglary, Vehicle Taking, Bunko Steering, Conspiracy to Commit a Felony, Escape from the State Farm, Failure to Provide, and Non-Support. The State Farm escapists were

TABLE 4

Distribution of "*M-F*" Scores for Each of Six Classifications of Offense

M-F Invt. No	Robbery	Larceny	Sex crimes	Checks	Embezzlement	Murder
(8)	0	0	0	1	0	1
(7)	1	4	1	0	0	1
(6)	6	4	0	0	0	1
(5)	1	6	6	3	0	1
(4)	8	8	4	3	1	1
(3)	6	16	11	2	1	2
(2)	7	17	2	5	2	0
(1)	5	11	8	2	1	1
(—1)	4	8	7	7	1	4
(—2)	3	9	3	3	1	5
(—3)	0	6	5	4	2	0
(—4)	1	2	2	1	1	2
(—5)	1	3	0	0	0	1
(—6)	0	0	1	0	0	0
(—7)	0	0	1	0	0	0
Number	43	94	51	31	10	20
Med. (intv.)	3.1	2.5	1.8	1.25	1.0	—0.5
Med. (score)	46.5	37.5	27.0	19.0	15.0	—7.5

larcenists who had been given additional sentences for escape, and the two men falling into the last two divisions were included on the doubtful assumption that Non-Support is a form of larceny through inaction.

Sex crimes include 1st and 2nd degree Rape, Assault and Battery with intent to Commit Rape, Incest, Pandering, and Sodomy. Checks include Forgery, Issuing Fraudulent checks, and Fraudulent checks. Embezzlement also includes Obtaining Money Under False Pretenses, Soliciting a Bribe, and Filing False Claims.

Murder includes 1st and 2nd degree Murder, Injury while committing a Robbery, and voluntary and involuntary Manslaughter.

It is to be noted that each distribution is fairly normal with the exception of the last one which is slightly skewed to the high or positive end. Reading from left to right, the median of the "*M-F*" score grows progressively more feminine.

Table 5 shows the relation between "*M-F*" scores and number of institution rule infractions committed by each of the 246 cases considered in this section.

Chief among the difficulties encountered in attempting to apply the Terman-Miles test to prison classification work in the Indiana State Prison were difficulties of administration.

TABLE 5
COMPARISON OF "*M-F*" SCORES WITH THE NUMBER OF INSIDE RULE INFRACTIONS

	Number of infiactions					
M-F Intv. No.	None	*F*	One-Nine	*F*	Ten-up	*F*
(8)	o	1		0		0
(7)	ooooo	5	oo	2		0
(6)	ooo	3	oooo	4	oooo	4
(5)	oooooooooooo	12	oooo	4	o	1
(4)	oooooooooooooooooo	18	oooooo	6	o	1
(3)	oooooooooooooooooooooooo	24	oooooooooooo	12	oo	2
(2)	ooooooooooooooooooo	19	ooooooooooooo	13	o	1
(1)	ooooooooooooooooo	17	ooooooooooo	11		0
(—1)	ooooooooooooooooo	17	ooooooooooooo	13	o	1
(—2)	ooooooooooooooo	15	oooooo	6	ooo	3
(—3)	ooooooooo	9	ooooooo	7	o	1
(—4)	ooo	3	oooo	4		0
(—5)	ooooo	5		0		0
(—6)		0	o	1		0
(—7)	o	1		0		0
	Number	149		83		14
	Median (intv)	1 4		1.0		2.5
	Median (score)	21.0		15 0		37.5

In order for an instrument to be of value as routine procedure it would be necessary for it to be applicable to nearly 100 per cent of the men admitted to the institution. As we have seen, approximately two-thiids of the men were eliminated because, as tested by the Morgan, they did not function on a mental level high enough to allow them to give a satisfactory performance. About 15 per cent of the remaining eligible group failed to complete the blank for a number of reasons. Physical disabilities accounted for some of them. Many of the men had such poor eyesight they were unable to see the test. A few were crippled so they were unable to write and seveial were in such a nervous state from the shock of incarceration that they were unable to concentrate upon the blank for the period required. The fastest and most conscientious workers completed the test in about an hour and ten minutes, while the slowest required approximately three hours. For the last group in particular, and for all inmates in general, a shorter period would be more desirable.

Motivational difficulties peculiar to the piison situation presented

themselves. Classification workers in most prisons are called "Bug Doctors," chiefly because these workers usually initiate the procedure required by law to have an inmate declared insane and "shipped over the wall" or transferred to the Indiana Hospital for the Criminally Insane. As a result, a summons to interview or test is regarded with a mixture of suspicion and resentment by many of the men.

The circumstances and attitudes which preceded a breech of the law coupled with the series of personal defeats represented by the subject's apprehension, trial, and incarceration all contribute in many cases to a condition of depression and negativism. Whatever motivational "set" is established toward conscientious performance under these adverse conditions is quite often interrupted completely when a convicted murderer comes upon an item which inquires how bad he thinks it is to put a tack in teacher's chair; or when a burglar, sitting among a dozen fellow burglars, is asked *"Do you ever dream of robbers?"* With a high percentage of negroes the question *"How much fear does a negro cause you?"* is likely to bring forth any number of reactions hardly conducive to conscientious work.

One administrative difficulty which was successfully avoided in the present investigation, but which would be a considerable factor should an attempt be made to use the test routinely, is the problem of the subject's knowledge of the purpose of the instrument. Terman and Miles show that knowledge of the purpose of the test had a tendency to cause fluctuation in the scores and with such knowledge in his possession a subject could influence his own score toward either extremity (1, p. 78). It would be extremely difficult to use the test, make recommendations from its performance, and carry out those recommendations without the real nature of the instrument becoming known. Once it became known within the institution, whatever value it may have had would become invalidated. This investigation was conducted without inmate assistance and the records were never out of the personal possession of the author; but classification committee records, while confidential, are available to a few inmates on the clerical staff.

Scoring is a rigorous task and at top speed the author was able to score about three blanks per hour. The task is exacting and requires highly accurate work. The clerical labor involved cannot

be done by inmate labor for many obvious reasons and the time required makes it impractical work for the professional staff members. The *"M-F"* or masculinity-femininity score which is a simple "plus-zero-minus" score was used in the present investigation. The *"I"* or "invert" score, while not tried here, might bring better results but would require the use of an adding machine and would increase scoring time to an hour or more per booklet, an obviously impractical situation.

In order for the test to have practical value it should be open to interpretation which would single out all or nearly all active homosexuals. As has been pointed out, inferior intelligence, physical disability, and lack of proper motivation eliminate considerably more than two-thirds of the inmates. No guess is to be made as to whether homosexuals fit more readily into the group which was acceptable or into the group which was not, but in eliminating such a bulk of the population there can be little doubt that a great number of what should have been positive cases are thus not eligible for test.

It is also to be considered that there are two recognized kinds of homosexuals; namely, the aggressive type or "wolf" and the passive type or "punk." It is generally agreed that only the latter type exhibit the feminine characteristics which would lead one to suspect that they would make a feminine score on a test of masculinity-femininity. The aggressive "wolf" would be indistinguishable from other males as far as masculine and feminine characteristics are concerned. But for prison disciplinary purposes one type is just as important as the other. However, if all the passive homosexuals could be detected, prison disciplinary problems would be considerably reduced.

Whether or not the few eligible homosexuals showed any characteristic performance on the test which would distinguish them from others may be seen in Table 1. A cursory examination of this table indicates that the positive cases are as normally distributed throughout the whole range of scores as could be expected from so few cases.

When the cases are analyzed individually as to whether they are aggressive or passive homosexuals, the following brief analysis presents itself. The five positive cases falling lowest on the scale or making the most feminine scores fall within a range of 90 points

out of 225. This represents 40 per cent of the total range. Of these five three are undoubtedly passive homosexuals and two are doubtful. Yet, even if we consider all of them as passive homosexuals, they are scattered over two-fifths of the total range and are indistinguishable, as far as test performance is concerned, from the other 50 men in the same distributional area. Thus 25 per cent of the positive cases and 29 per cent of the negative cases are included in the most feminine 40 per cent of the range.

On the masculine end of the distribution the four positive cases making the most masculine score included one which was definitely the passive member, one who was the aggressive member, and two who were doubtful. They, too, as far as test performance is concerned, are indistinguishable from numerous negative cases falling above and below them.

Thus known passive homosexuals have made scores which placed one in the class interval once removed from the extreme masculine end of the distribution, and one in the class interval once removed from the extreme feminine end of the distribution. Although the positive cases here available are not numerous enough for statistical treatment, it seems obvious that this test, under these circumstances, will in no way point out the active homosexuals in the prison population.

Therefore, when all these difficulties are considered, it seems that it can be safely stated that the Terman-Miles *Attitude-Interest Analysis Test* is of little practical value as a diagnostic tool in the detection of active homosexuals in the population of the Indiana State Prison.

In regard to the relation between *"M-F"* scores and mental ages the arbitrary limitation set upon the Morgan score necessary before the Terman-Miles test was presented eliminated approximately 65 per cent of the prison population. Since the limitations set by Terman and Miles (various for various groups, 11-21, 11-18 and 12-21 years in terms of mental age) (1, p. 149) were approximately the same as those of this study (above 12.4), it seems safe to assume that correlations obtained by those authors cover approximately the same fraction of the total distribution of mental ages as does the correlation obtained in this study. While Terman and Miles obtained correlations ranging from .00 to .33, their largest groups, with one exception, ranged from .19 to .24. Thus, since the cor-

relation obtained in this study was .22, it seems we can affirm a slight positive relationship between the two measures.

In considering the relationship between "*M-F*" scores and the total number of months a subject has spent in prison it becomes immediately evident that the factor of age might be operating in this instance. There must be a relatively high correlation between age and the number of months served. Terman and Miles (1, p. 123) showed that there was a marked, steady decrease in the "*M-F*" scores between the ages of 30 and 80, roughly the ages with which we are dealing since 30 is the dividing age between men sent to the Indiana Reformatory and the Indiana Prison. Although they give no correlation coefficient for this group, it is obvious from inspection that the correlation is negative and very high. Thus if age alone was responsible for the length of incarceration in the cases considered, we should expect to get a high negative correlation instead of the small positive correlation obtained. Thus we can probably intimate that those who spend much of their lives in prison have a tendency to get scores which are more masculine than those who don't or that long incarceration in prison tends to prevent the downward drop toward the feminine end of the distribution characteristic of scores by age.

The "*M-F*" score as compared to the type of offense yields an interesting surprise. It seems natural that those who fall in the Robbery classification, those who have perpetrated violent property offenses with firearms, should make the most masculine score. The less adventurous property offense seems natural in second place, as do the forgers in fourth, and the embezzlers in fifth, as one might be tempted to accept these classifications in that order when the overt boldness and thus questionable masculinity of the offense is considered. The sex offenses in third place seem natural enough since, on the same passive-aggressive scale, this group includes many widely variant acts. But the murderer, the person who deliberately takes the life of another, seems very much out of place, making the most feminine score of all. For an accurate explanation of this phenomenon it would be necessary to make an exhaustive study of the 20 cases available.

Comparison of "*M-F*" scores with the number of institution rule infractions indicates that those men who have been reported from one to nine times, those who might be considered minor disciplinary

problems, made the most feminine score, with those who have never been reported making a slightly more masculine response. The major disciplinary problems, however, those who have been punished 10 or more times make a much more masculine score than either of the other groups.

There is some possibility that the difference between the first and second groups may be rationalized to some extent on this basis.

Since quite a few of the men tested were new admissions, those who would eventually become disciplinary problems, had, by the time this paper was written, little time in which to be reported for infraction of the rules. Those in the second group, by the very fact that they had "inside records" to their credits, must have, as a group, been incarcerated for a longer period. No attempt was made to verify the number of "Fish" in the first group as compared to the number in the second group since this problem is of the calibre and importance to give it standing as a separate research problem.

Summary

The prime purpose of this investigation was to determine if the *"M-F"* test could be of any practical value in prison classification work. It seems from the data at hand that there are several difficulties incumbent upon its use.

First are the administrative difficulties. It requires more time to administer than is optimal under existing conditions. Approximately two-thirds of the prison population is eliminated because it is unable to give a satisfactory performance because of limitations of mental ability as measured by the Morgan test. A great number of men are unable to complete the blank because of physical disabilities. It is difficult to sustain motivation in such circumstances, with such subjects, over such a long period of time when items tend to aggravate factors tending to despoil good motivational "set." The chances of information leaking out which would nullify the results is too great for constant, routine application. The ponderous scoring procedure cannot be handled adequately under existing facilities.

As for interpretation in regard to homosexuality, passive homosexuals, from the data available, are just as likely to make a high masculine score as a high feminine score, and aggressive homosexuals make scores which are almost as widely scattered. No criterion of

test performance could be found which would point out members of either group.

The relationship between *"M-F"* scores and Mental Ages is slightly positive and to a degree consistent with the results obtained by the authors of the instrument.

The type of offense yields data showing that Robbers make the most masculine score and Murderers the most feminine, with the sex offenders and the lesser property offenders falling in between. No explanation is offered for the femininity, as measured by this test, of the Murderers as a group.

There is a slightly positive relationship between *"M-F"* score and total time served, which indicates either that the fact of incarceration tends to cause a subject to make a more masculine score or that the subjects who are most consistently in serious trouble with the law make more masculine scores.

Comparison of *"M-F"* scores with the number of inside rule infractions indicates that while the test cannot very well be used as a tool for the prediction of behavior in any individual case, those who consistently violate the rules of the institution make, as a group, more masculine scores than those who conform while incarcerated.

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Indiana State Prison
Michigan City, Indiana

The Journal of Genetic Psychology, 1941, **59**, 41-49.

THE INHERITANCE OF BRIGHTNESS AND DULLNESS IN MAZE LEARNING ABILITY IN THE RAT*

Department of Psychology, University of Minnesota

W. T. HERON[1]

A. INTRODUCTION

In 1935 I reported the results of an experiment on selective breeding of rats for maze learning ability (3). At that time the results for only four generations and the parents were available. At the present time the 16th generation has completed its training. This report, therefore, will give the additional data together with comments and interpretations based upon the additional experience with the problem.

For the apparatus and technique of running the animals the reader is referred to a paper on the automatic maze (4) and to the previous report on breeding (3). Efforts have been made to keep running conditions as uniform as possible from generation to generation. The only significant deviation from the procedure as previously outlined is that I have paid less attention to litter size, the quickness of breeding, and close inbreeding than previously. The rats have remained healthy, and normal litters have been born. The only unhealthy sign which has been noted is that a number of the bright females develop a blocking of the intestinal tract. It is probably some form of tumor. It usually develops some time after the birth of the litter and is, therefore, not serious so far as the maintenance of the strain is concerned. This disorder occurs in other rats but very infrequently.

B. RESULTS AND DISCUSSION

Figures 1 and 2 show the distributions for the various generations. It will be noted that there has been a certain amount of fluctuation from one generation to another. Other than this, the distributions tell little. A more detailed analysis can be made by a study of Table 1. In this table will be found the means and other

*Received in the Editorial Office on March 16, 1940

[1]The author is grateful to the National Youth Administration for help received in the preparation of this paper.

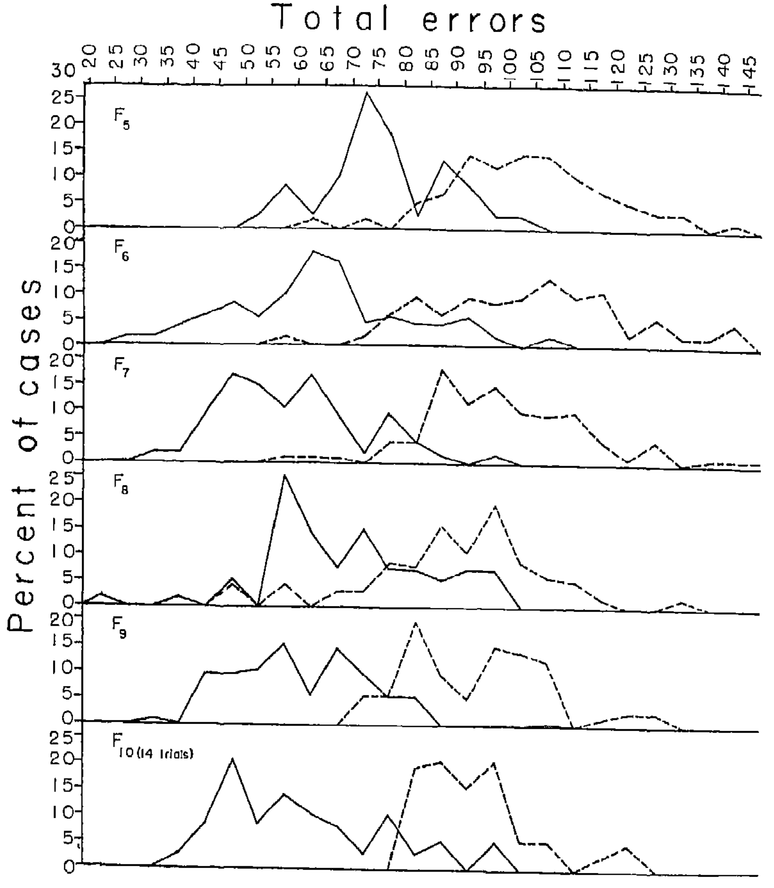

FIGURE 1

Distributions from the 5th, 6th, 7th, 8th, 9th and 10th Generations

The dotted lines represent the dull rats. The distiibution for the dull rats of F_7 omits two animals as their inclusion would have extended the figuie unduly. One animal made a total of 155 eiiois, the othei 190.

measures for the brights and dulls from the 5th to the 16th generation, inclusive. All generations were run 17 trials save the 15th which was given 32 and the 14th which was run for 16 trials. The means do not include the scores for the first two trials.

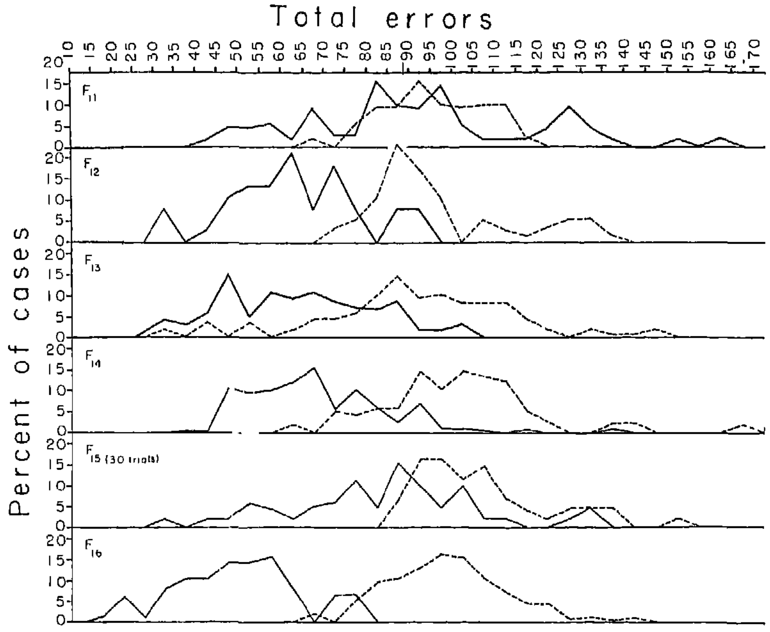

FIGURE 2

DISTRIBUTION FOR THE 11TH, 12TH, 13TH, 14TH, 15TH AND 16TH GENERATIONS F_{15} were run for 30 trials, but the distribution is based upon 15 trials only in order to make it comparable with the others.

There are several points to be noted in this table. First, there is a good deal of fluctuation in the mean score from one generation to another. The causes of these fluctuations are not apparent to me except as noted in the table. As I have indicated above, we try to handle and run the animals in the same way from generation to generation. Apparently, however, there are some factors which are *not* being controlled. It will be noted also that the two strains tend to vary together, which indicates that these factors are of an experimental variety. If the fluctuations were caused by poor selection of the parents it is improbable that there would be concommitant variation in the strains. This concommitance is measured roughly by a correlation of +.58 between the means not including the 15th and 16th generations. Although this failure to control factors is

TABLE 1

DATA OF 5TH TO 16TH GENERATIONS, INCLUSIVE

Generation		No cases	Mean error per rat	σm	D	σd
F_5	D	55	103.59	2.04	26.84	2.76
	B	34	76.75	1.84		
F_6	D	53	111.65	2.52	50.55	3.52
	B	50	61.1	2.46		
F_7	D	73	74.05	2.45	15.40	3.07
	B	53	58.65	1.85		
F_8	D	63	102.1	2.56	45.85	3.54
	B	44	56.25	2.45		
F_9	D	32	108.75	2.71	36.60	3.55
	B	43	72.15	2.30		
F_{10}	D**†	41	109.55	1.62	36.10	6.34
	B	37	73.45	6.13		
F_{11}	D	51	120.9	2.83	37.40	3.74
	B	49	83.5	2.45		
F_{12}	D	55	117.75	2.28	52.55	3.19
	B	37	65.2	2.33		
F_{13}	D*†	130	103.85	1.93	30.20	2.76
	B	75	73.65	1.97		
F_{14}	D	78	113.15	2.24	27.55	2.93
	B	89	85.60	1.89		
F_{15}	D‡	48	195.0	7.01	46.00	9.18
	B	50	149.0	5.92		
F_{16}	D	130	116.05	1.35	69.15	2.08
	B	75	46.9	1.58		

**† F_{10} rats run 16 trials only.

*† In the F_{13} generation the error recorder for unit 6 was inadvertently disconnected. This affects the mean error.

‡ The data for this generation are based upon 30 trials.

disappointing, the fluctuation in results nevertheless has an interesting implication. It indicates that there are environmental conditions which will increase the efficiency of the dull rats. For example, there is a difference of approximately 37 errors in the means of the F_6D and the F_7D. This difference is statistically significant. There are, of course, differences between the various generations of brights also but it is well known that there are many environmental factors which will lower the efficiency of the organism. The more interesting and important problem is to find an environment which will cause the organism to respond more efficiently than would be predicted on the basis of its ancestral history. Or perhaps a better statement of the problem is: what is the environment which will enable the organism to realize to the highest possible degree the

potentialities of his heredity? The immediate and specific problem in the present case is to discover the environmental chances which have been inadvertently introduced in the experiment.

Secondly, the greatest deviation from this trend is found in the 16th generation where the mean for the brights falls to its lowest level while that for the dulls is consistent with previous generations. The probable explanation is that this maze situation has reached the limit of its discriminative power so far as the dull rats are concerned and also for the bright rats if they are given only 17 trials. However, additional trials in the maze tend to increase the discrim-

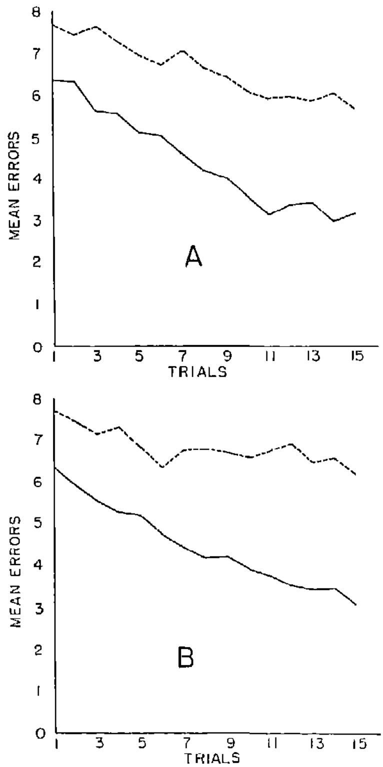

FIGURE 3

Learning Curve

A is for the 5th, 6th and 7th generations combined *B* is for the combined 14th, 15th and 16th generations. Dotted lines represent the dull animals.

inative power for the bright rats. Thus in the 15th generation with a 32-trial run we made a better selection among the bright animals with the result that their offspring markedly reduced their mean error score. A glance at the learning curve (Figure 3) for the dull rats for the last four generations will indicate to the reader that these animals never reduce their errors below the chance level. Chance in the present maze should give a mean of six errors per trial as there are 12 alternatives.

The problem which faces us is one which is familiar to those who work with tests for human subjects. The differences in the scores for the dull rats do not reflect differences in ability to any appreciable extent because the problem is too difficult for all of them. It is hardly likely that the group is in reality homogeneous in ability. Real differences in ability must still exist. The problem is to make them apparent. The obvious answer is to make the problem easier, but if this is done it is likely to cause a loss of discriminative power for the bright animals. Another answer is to run the dull rats on one problem—perhaps on six units of the maze instead of 12—and the bright animals on the whole maze as before or perhaps even extend the problem to 15 or more units for them. Only experimentation can indicate whether this will be the solution, as it is impossible in the a priori reasoning to take into account all of the intricate relationships which may be involved in the learning of the maze pattern. Still another possible solution is to run the animals in a number of different mazes and to select on the basis of a combined score. The time required to do this should be prohibitive. Another suggestion by Dr. H. P. Longstaff is of interest. It is to run all rats in two units of mazes to a criterion of learning. As each rat reaches the criterion add a unit for it and when it reaches the criterion in the three units repeat the procedure. We would thereby measure what we might call the "maze mental age" of each animal. Selection for breeding would be on the basis of this "mental age."

This is an ingenious suggestion and holds important possibilities. There are, however, some technical difficulties. It is possible in the maze which is used to allow the animals to run through any number of the 12 units and to finish the distance to the food by going through the tunnel which runs underneath all of the units. However, unless the readjustment of the maze for each rat can be solved by an automatic arrangement, the plan would be very time con-

suming. Also, there would arise the question of how many trials to allow the animal on a given number of units before deciding it to be beyond his capacity. This limit would have to be set arbitrarily. Other problems would no doubt arise but possibly all can be solved.

Figure 4 illustrates anothei relationship which has been found

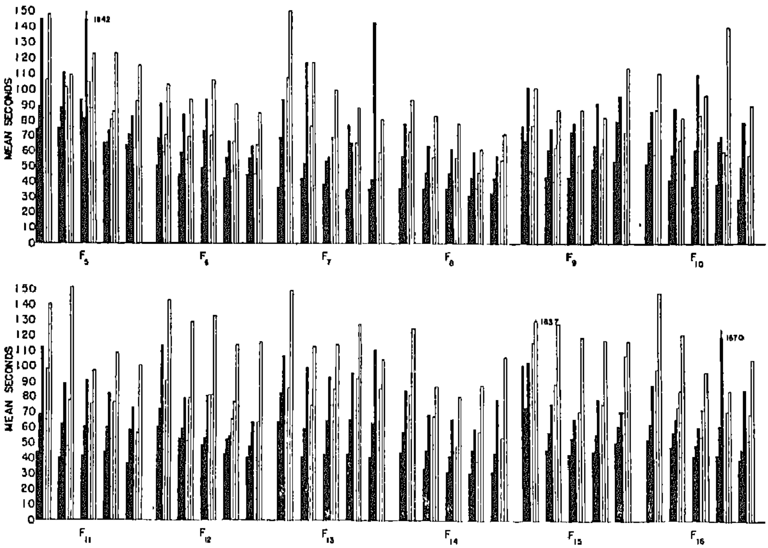

FIGURE 4

HISTOGRAM SHOWING THE DIFFERENCE IN TIME BETWEEN THE DULL AND BRIGHT ANIMALS FOR TRIALS WITH SAME NUMBER OF ERRORS AND AT DIFFERENT STAGES OF LEARNING

The brights aie represented by the solid black. The figure ieads as follows: starting in uppei left-hand coinei, the first step in the solid black indicates the mean time foi bright rats in Trials 1 to 3, inclusive, in which 1 to 3, inclusive, eiiors were made. The next step is for Trials 1-3 in which 4-6 errors weie made, and the next Trials 1-3 in which 7-9 eiiors weie made. The three open bars repeats this foi the dull iats. The next group of 6 bars aie for Tiials 4-6, the next for Trials 7-9, and so on to Trials 13-15. The whole procedure is repeated for the F_6 geneiation and for each succeeding generation.

to exist. The dull rats progress through the maze at a lower rate of speed than the brights. This fact was first noticed by Harris and his interpretations based upon it will be found in his articles (1, 2). It is to be expected that an animal which makes more

errors than another will take longer to go from the beginning to the end of the maze. In order to eliminate this factor as much as possible the mean time for runs involving the same number of errors has been calculated for both the brights and the dulls. As indicated on the figure this has been done for various portions of the learning curve. With very few exceptions the brights show a faster time than the dulls. The exceptions which do occur can be accounted for in terms of the abnormal behavior of one or two rats.

Figure 4 does not show times for correct runs or for runs in which more than nine errors were made. A calculation shows, however, that in all 12 generations under consideration in this paper the dull rats have made a total of only 28 errorless runs with a mean time of 113.2 seconds per run. The bright rats have made a total of 334 such runs with a mean time of 32.2 seconds. On the other hand, the dull rats have made 289 runs in which there were 12 errors or more with a mean time per run of 610.4 seconds, while the bright rats have made 42 of these runs with a mean time of 939.8 seconds. Apparently when the bright rats become confused they are very hesitant in their running.

It might reasonably be assumed that the fact that a larger time is required by the dull rats indicates a difference in motivation, and that this difference in turn would account for the difference in learning. This possibility was examined by Harris (1, 2), and he concluded that while the two strains differed in motivation under the maze running conditions, this difference was not sufficient to account for all the difference in learning.

C. Conclusions

1. There can be no question that maze learning is largely determined by hereditary characteristics. Strictly speaking, this statement should be qualified by designating the maze learning as the learning of the particular maze employed. However, unpublished evidence shows that these rats will differ in their learning of the Stone Multiple-T maze also. To what extent there is a generalized maze learning ability can only be determined by further experimentation.

2. The evidence indicates that the maze problem as used at present in this experimentation has no further discriminative power for the dull rats, and that the validity of selection of bright rats would be increased by increasing the number of trials or possibly by increasing the number of units in the maze.

3. It is felt that some evidence has been presented which bears on the question of the influence of heredity, and suggests the problem of specifying the optimal environment for the realization of hereditary potentialities.

4. As a general rule, the dull animals take longer in running the maze than the brights when errors are held constant.

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Department of Psychology
University of Minnesota
Minneapolis, Minnesota

The Journal of Genetic Psychology, 1941, **59**, 51-64.

THE BRAIN MINERALS AND LEARNING ABILITY OF ALBINO RATS*

Departments of Education and Chemistry, Kansas State College of Agriculture and Applied Science

O. W. ALM AND C. H. WHITNAH[1]

A. INTRODUCTION

The recent finding by Dale, Feldberg, and Vogt (7) that acetylcholine is the active agent in the innervation of striated muscles and probably in the synaptic connections between neurons, emphasizes the general idea that chemical reactions are essential to nerve functions. Much has been written, even in popular literature, about the relationship between excitability and the assimilation of calcium. There is much discussion about the importance of alkaline and acid conditions of the body. Occasionally statements are made about the depressing effects of potassium. Moreover, the statement by Liebig (16), "Ohne Phosphor Keine Gedanken," expresses an idea that has been rather widely and uncritically accepted.

1. *Phosphorus*

Liebig's conclusion has some foundation. Studies reported by Koch and Koch (13), Hess, Gross, and Weinstock (11), and Gerard (10) indicate that the nervous system contains a considerable amount of phosphorus. But the significance of phosphorus in the nervous system is more a matter of its distribution and its reactivity in neural functions than of its amount. Koch and Koch (13) described the content of phosphorus in the nervous system as consisting of three groups: protein phosphorus, lipoid phosphorus, and water soluble phosphorus. "The protein phosphorus is largely associated with the nucleic acid of the nucleus" and possibly with the nissl substance. Lipoid phosphorus, as phosphoric acid, is in the fat like materials called phospholipids. These lipids are associated with the

*Received in the Editorial Office on April 1, 1940.

[1]The psychological work was done by O. W. Alm of the Department of Education. The chemical analyses were made by C. H. Whitnah as contribution No. 252 of the Department of Chemistry, Kansas Agricultural Experiment Station

cell body and fibers of neurons, but especially with axons during their rapid growth. No report was made concerning the distribution of water soluble phosphorus.

How important the content and distribution of phosphorus may be in neural activity is not clear. Mathews (16) claimed that it had a part in the regulation of cell acidity and that a high intake of phosphorus and a low intake of calcium produced abnormal irritability of the nervous system. Gerard (10) related that it had been found that "phosphorus . . . is unequally distributed in resting nerves, the distal portion being richer; but during activity there is a migration toward the proximal end, opposed to the direction of impulse travel." On these findings Gerard made the following comment: ". . . The prevailing theory of nerve conduction calls for such a displacement. . . ." But he said, "Our own results on the migration or displacement of phosphate have so far been negative." Eaves (8) claimed that "poor myelinization is always accompanied by a low phosphorus content of the cerebral cortex. On the other hand, the latter may be low where myelinization is excellent." The behavioral significance of phosphorus is strongly suggested by data from human pathology. Eaves (8), Koch and Mann (14), and Pighini (22) have reported considerable evidence that low brain phosphorus is associated with such degenerative nervous diseases as arterio-sclerotic insanity, general paralysis, and Huntington's chorea. Studies reported by Alm and Whitnah (1) indicated a positive relationship between unsaturated phospholipids and learning ability in rats. In conclusion it should be noted that the data on the content of phosphorus in the nervous system, on its intimate association with neural activity, and on the deficiency of it in degenerating brain diseases are considerable and cannot be disregarded.

2. *Sodium*

If the significance of phosphorus in brain action is not clear, the significance of sodium is even more uncertain because the data on sodium are decidedly more fragmentary. As to content, the studies reported by Ballif and Gherscovici (2), Koch and Koch (13), Gerard (10), and Koch and Pike (15) all indicate considerable amounts of sodium in nervous tissue. There is also some data on its distribution and neural functions. Koch and Koch (13) referred to it as one of the inorganic cations of the nervous system. Koch and Pike (15) found it combined with cephalin and lecithin of the

lipoids in neurons. In neural activity it seems to be most closely related to respiration. Gerard (10) pointed out that sodium sulphate has been found to accelerate carbon dioxide production and oxygen consumption. He noted also that nerves placed in saline solutions to which certain calcium ion removers such as phosphate, sulphate, fluoride, oxalate, and citrate had been added showed a marked increase in respiration.

The significance of sodium in the nervous system is also suggested by some data on the effects of pathological organic conditions. Ballif and Gherscovici (2) found a marked change in the values of sodium and potassium in the brains of pigeons on a vitamin *B* deficient ration. The values were for sodium .85 and for potassium 3.6 per 1,000 parts as compared with the normal condition of sodium 1.48 and potassium 2.4. The values respectively for men dying from pellagra were 1.0 and 3.0 as compared with 1.4 and 2.4 for men dying from other diseases. This means a large increase in potassium and a large decrease in sodium in pellagra and in experimental vitamin *B* deficiency. It seems safe to conclude that sodium must have a significant part in the action of the nervous system. But what may be the direction of its influence in higher mental processes or higher behavioral adjustments is hardly suggested by the foregoing data.

3. *Magnesium*

The neural significance of magnesium is not well known. Novi (18) made one of the most significant findings. He claimed that he found its concentration in dogs' brains remained constant all through life and that it was not affected as calcium is by injections of sodium chloride. Koch and Koch (13) referred to magnesium as one of the inorganic cations of the nervous system. They noted that magnesium, like calcium, has a "tendency to remain combined with the proteins." Bodansky (4) said that the deprivation of magnesium results in hyperirritability of the nervous system and tetany. This would seem to indicate that it is an important chemical factor in neural functions.

4. *Potassium*

The studies on the potassium of the nervous system are numerous as compared with those on magnesium. There are considerable data concerning the content of potassium in the nervous system. The

analyses reviewed by Gerard (10) indicated significant concentrations of potassium in the nerves of different animals. Concerning its distribution he concluded that "Histo-chemical studies have shown little or no potassium within the intact axis cylinder but considerable amounts about it at the nodes of Ranvier, and in the myelin." Koch and Pike (15) found that both sodium and potassium occur in the lecithin and cephalin of neurons.

Potassium appears to be definitely related to the irritability of the nervous system. In experiments by Menten (17) on the sciatics and nerves from the brachial plexus of dogs, injections of 19 different potassium salts were made. Fourteen of these solutions blocked the conduction of nerve impulses from one to three hours. Pichler (21) concluded that, "The relative quantities of two forms of potassium (potassium insoluble in water-free lipoid solvents, and potassium soluble in lipoid solvents only on the addition of water) vary with the state of excitation of the central nervous system." Gerard (10) reported that, "Experiments on dog and frog sciatics indicated a shift of potassium ions from the central stimulated portion toward the peripheral end; that is, in the direction of the conduction of nerve impulses. The concentrations in proximal, middle and distal regions were equal in resting nerves but unequal . . . after long tetanization." The close association of potassium and calcium ions with the conduction of nerve impulses is especially significant in view of recent findings by Brown and Feldberg (6). They claim that Cowan found a definite association between the mobilization of potassium ions and the propagation of nerve impulses in crab's peripheral nerves and that in their own studies of the effects of potassium ions on the perfused superior cervical ganglion of the cat they found: (1) "Small doses of potassium chloride injected in the perfusion fluid increase the response of the ganglion to single submaximal preganglionic volleys"; (2) "Potassium ions liberate acetylcholine from the normally innervated ganglion"; and (3) "In large doses potassium has a paralyzing effect on ganglion cells." These findings are significant for the study which is reported in this manuscript. But it should be noted that Ballif and Gherscovici (2) found that under the conditions of vitamin *B* deficiency, produced experimentally, the brain potassium in pigeons was considerably increased over the normal values. They found a similar change in potassium in the case of men dying from pellagra. It might also be observed that in Addison's disease where there is a marked

deficiency in the adrenal hormone, cortin, that the depression of the nervous system is associated with a marked increase in potassium. The presence of potassium in the nervous system, its definite association in small amounts with conduction processes, and its depressing influence in the excessive amounts found in pathological conditions leads one to believe that even in its more normal variations it might have some influence upon learning ability.

5. *Calcium*

Calcium constitutes a large part of the mineral content of nerve tissue. This is evident in the studies reviewed by Gerard (10) and in those reported by Hess, Gross, and Weinstock (11) and Novi (18). Concerning the effects of calcium on neural functions the most significant recent finding was reported by Brown and Feldberg (6). They found that "Calcium inhibits the liberation of acetylcholine." Marked changes in the content of brain calcium have been produced by thyroparathyroidectomy in dogs and cats (20), subcutaneous injections of solutions of calcium chloride in dogs (19), experimental rickets in rats (11), and cretinism and Huntington's chorea (8). Hess, Gross, and Weinstock (11) reported that low blood calcium due to parathyroidectomy produced tetany, but they reported no evidence of tetany or other manifestations of excitability resulting from marked reductions in brain calcium.

6. *Conclusions*

The literature indicates these significant facts concerning the minerals of the nervous system. (1) There is a considerable content of phosphorus, potassium, sodium, calcium, and magnesium. (2) There is much evidence of marked variability in the total amount and concentration of these minerals. (3) There is also some data indicating the importance of each of these minerals for neural activity and behavioral variation. (4) Only two general methods have been used to test the more direct relationship between the minerals of the nervous system and behavioral adjustments. They are: (*a*) the study of the consequences of experimental deficiency and (*b*) the investigation of mineral variations resulting from degenerating diseases. No records have been found of attempts to study the relationship between the variations of minerals in normal nervous structures and the behavioral adjustments of the organisms involved. Such studies are essential.

For the study of brain minerals as reported in this manuscript it was decided originally to measure phosphorus, sodium, potassium, and calcium. Magnesium was added for the second group of animals.

B. Methods of Mineral Analysis

The following methods were used in the analysis and measurement of the minerals:

1. The fresh brain was covered with nitric acid and heated. Nitric and perchloric acids were added as needed until the material was completely dissolved. The solution was then evaporated to dryness, taken up in hydrochloric acid and again evaporated until all nitrates were removed. Aliquots of the hydrochloric acid solution were used for each analysis.
2. Phosphorus was measured colorimetrically by the method of Fiske and Subbarow (9).
3. Calcium was precipitated as oxalate and titrated with permanganate as described by F. C. Koch (12).
4. Magnesium was precipitated as phosphate from the calcium filtrates, and the precipitated phosphorus measured colorimetrically according to the methods outlined by A. P. Briggs (5).
5. Potassium was precipitated with platinic chloride and measured colorimetrically as indicated in Yoe's Methods of Colorimetric Analysis (23).
6. Sodium and potassium were measured together as mixed alkali and the sodium obtained by difference, a method used by R. S. Barnett (3).

C. Learning Procedure

For measuring learning ability two different mazes, Maze *B* and Maze *C*, were used. These were the same mazes as used in a previous study by Alm and Whitnah (1). Maze *B* was a hard, enclosed maze. Maze *C* was a partly enclosed, elevated, multiple-*T* maze. The order of learning was Maze *C* first and then Maze *B*. Just before the regular trials started in either maze all animals were given group orientation trials. Three or four animals were placed in the maze together and given all the time they required to move through to the food box. In Maze *C* four such trials were necessary and adequate for most animals to develop reasonably free or spontaneous running. Maze *B* required only two such trials. The dis-

tribution of practice was two trials per day for Maze *C* and five trials per day for Maze *B*. All rats in Group I (described below) were given 30 trials in Maze *C*, an intermission period of 30 days without maze running, and then 70 trials in Maze *B*. Group II (described below) received 22 trials in Maze *C* and 50 trials in Maze *B*, without any intermission between the mazes.

D. Animals

The animals used in this investigation were two groups of male rats of pure albino stock. Group I consisted of 40 animals raised in the psychology animal room from a purebred Wistar strain. Group II consisted of 71 animals purchased from Sprague-Dawley, Madison, Wisconsin. Group I were 44 to 48 days of age at the time of beginning learning and 129-135 days of age when they were killed for brain analysis. Group II were 49 days of age at the time of beginning learning and 70-75 days of age when they were killed for brain analysis. The feed previous to, and all through learning consisted of a mixed ration of ground feed.[2] The procedure in feeding follows in full. For one week previous to beginning learning and during learning in Maze *C* the animals in both groups were fed, in small groups of four to six animals, 5 grams of ground feed per animal. During learning in Maze *B* they received 7 grams instead of 5 and were fed individually. In addition each rat received sunflower seeds as bait in the food boxes of both mazes. During the 30 days of intermission between learning Maze *B* and beginning Maze *C* Group I received 12 grams of this ground feed per animal per day. The animals in Group II with one exception were fed in the same manner as Group I. They had no intermission between learning Maze *C* and beginning Maze *B*.

E. Results

The original data obtained by the foregoing procedures consisted of four learning scores and four or five mineral scores per animal. The learning scores were time in total seconds (number of trials constant), and total errors (number of trials constant) for each

[2]The ration consisted of 55 parts of whole wheat flour, 25 parts of corn meal, 10 parts of powdered milk, 6 parts of meat scrap, 3 parts of alfalfa leaf meal, 1 part of salt and 2 parts of cod liver oil. The feed excluding cod liver oil was mixed, ground and reground very fine. The cod liver oil was mixed into small batches of this feed as fed.

maze. The mineral scores were the total weights of each mineral per brain as calculated from the content found in the aliquots taken for analysis. These weights were also converted into measures of concentration. The measure used was micrograms per 100 grams of fresh moist brain.

The coefficients of correlation between the mineral weights and the learning scores are presented in Table 1. What do these coefficients of correlation indicate? Take phosphorus. For this mineral all of them are low. Not one is statistically significant. But it should be noted that they are generally positive and not negative. The status of sodium is somewhat different. All but two coefficients are low, and those two are statistically significant. The most noticeable fact about sodium is the change in the sign of the coefficient found in the results from the two groups of animals. There was nothing apparent in the procedures and the handling of data that could account for such a difference. There were important differences in stock and age of the two groups of animals. It is not likely that stock produced any difference. But since sodium is definitely related to the excitability of nerve tissue, is it possible that age made a difference? This should be tested under well controlled conditions.

TABLE 1
COEFFICIENTS OF CORRELATION BETWEEN LEARNING SCORES* AND MINERAL WEIGHT SCORES

Mineral	Group of animals†	N	Maze C Time	Maze C Errors	Maze B Time	Maze B Errors
Phosphorus	I	40	+.267	+.223	+.038	+.028
	II	71	—.183	—.087	+.074	+.226
Sodium	I	40	—.405	—.424	—.170	—.024
	II	39	+.053	+.156	+.195	+.190
Potassium	I	37	—.161	—.151	—.465	—.427
	II	39	—.104	—.194	—.165	—.174
Calcium	I	40	—.122	—.190	+.075	+.100
	II	71	+.122	+.107	—.009	—.076
Magnesium	II	71	—.182	—.072	—.173	—.022

*Since the larger the time and error scores are, the poorer the learning ability, negative correlations indicate positive relationships and positive correlations indicate negative relationships between mineral content and learning ability.

†The animals in Group I were 129-135 days old and those in Group II were 70-75 days old when they were killed for mineral analysis.

The most significant relationship between any one mineral and

learning ability was found for potassium. The coefficients all indicate a positive relationship to learning ability. Two of them are statistically significant although most of them are low. But this is not surprising if one considers how many other things than potassium (other chemical components for example) may affect learning ability. Moreover, in view of the consistency of the coefficients, one is tempted to conclude that they are more significant than their magnitude might indicate. This finding seems to correlate with the results obtained by Brown and Feldberg (6) in experiments on the effects of potassium chloride on the superior cervical ganglion of the cat. They found that in small doses potassium not only liberated acetylcholine but directly increased the response of the ganglion, whereas only in large doses did potassium have a paralyzing effect. This probably means that up to a certain concentration it facilitates neural activity instead of depressing it.

The coefficients of correlation between the calcium content and learning ability are all low. Moreover, they indicate no agreement either between mazes or between ages of animals. These findings are somewhat surprising in view of the findings from other studies concerning the relationship of calcium to excitability. The lowest coefficients for any mineral, however, are those obtained for magnesium. They are all negative, but they are so low that they may indicate no relationship between magnesium and learning ability.

The coefficients of correlation between learning scores and mineral concentration scores are presented in Table 2. A glance over the

TABLE 2
COEFFICIENTS OF CORRELATION BETWEEN LEARNING SCORES* AND MINERAL CONCENTRATION SCORES

Mineral	Group of animals	*N*	Maze *C* Time	Maze *C* Errors	Maze *B* Time	Maze *B* Errors
Phosphorus	I	40	+.263	+.081	+.128	+.017
	II	71	—.020	+.004	+.112	+.301
Sodium	I	40	—.378	—.424	—.142	—.026
	II	39	+.122	+.197	—.039	+.152
Potassium	I	37	—.054	—.203	—.202	—.312
	II	39	—.067	—.165	—.204	—.193
Calcium	I	40	—.109	—.211	+.114	+.171
	II	71	+.174	+.144	—.104	—.054
Magnesium	II	71	—.097	—.029	—.145	—.037

*In these coefficients as in those for mineral weights, positive signs indicate negative relationship and negative signs indicate positive relationship with learning ability.

table reveals that these coefficients are very similar to those in Table 1.

The coefficients presented in Tables 1 and 2 may not indicate very closely the actual relationship between particular minerals and learning scores, because of the interrelationships between the different minerals. The coefficients of correlation between the several minerals were as follows: potassium and sodium +.393, potassium and phosphorus +.366, potassium and calcium +.347, sodium and phosphorus —.034, sodium and calcium +.374, and phosphorus and calcium +.164. Since there was no method by which the variations in minerals could be controlled, the partial correlations for the mineral concentrations and learning ability were determined for Group I and are given in Table 3. By this technic three different minerals taken as inde-

TABLE 3

COEFFICIENTS OF PARTIAL AND MULTIPLE CORRELATION BETWEEN LEARNING SCORES AND MINERAL CONCENTRATION SCORES*

Mineral	Maze *C* Time	Maze *C* Errors	Maze *B* Time	Maze *B* Errors
Partials for:				
Phosphorus	+.238	+.107	+.194	+.153
Sodium	—.332	—.331	+.087	+.061
Potassium	—.289	—.061	—.271	—.416
Calcium	—.015	—.065	+.212	+.284
Multiples for:				
Four minerals	+.454	+.439	+.359	+.437

*Since the larger the time and error scores are, the poorer the learning ability, negative partial correlations indicate positive relationships and positive partial correlations indicate negative relationships between mineral content and learning ability. The multiple correlation is always positive.

pendent variables were in each case held constant and each partial coefficient presented in the table is supposed to represent a relationship between a particular mineral and a particular measure of learning ability taken independent of the influence of other minerals. It may be seen that the partial correlations are not very different from the zero order of correlations presented in Table 2. The partials for potassium and phosphorus are in some cases higher. Those for sodium are slightly lower and contradictory for the two mazes. Those for calcium are slightly higher for Maze *B*, but are still contradictory for the two mazes.

The multiple correlations for the four dependent learning variables

are also presented in Table 3. They may indicate the maximum combined influence of the four minerals (taken together) upon learning ability. They may also indicate roughly the extent to which maze learning ability in rats is due to the combined influence of these four minerals, and not to other factors.

F. Discussion and Evaluation of Findings

The significance of the findings just presented and the advisability of further studies along this line require a careful consideration of some related factors and findings. In the first place, the studies of rat brains by Koch and Koch (13) indicate that the big, rapid changes in the per cent of solids, proteins, phospholipids, total sulphur, and total phosphorus take place before 40 days of age. Consequently, since both groups of animals in this study began learning after 44 days of age and were analyzed after 70 days of age it is hardly possible that chemical changes during the learning period and previous to analysis had any considerable effect upon the findings obtained.

In the second place, the amounts, concentrations and variability of brain minerals are important factors in the coefficients of correlation. The averages and the standard deviations of the mineral measures are presented in Table 4. The deviations indicate individual differences that are not only marked for both total weights and concentrations but surely adequate for bringing out any existing relationship between minerals and learning ability.

TABLE 4
AVERAGES AND STANDARD DEVIATIONS OF BRAIN MINERALS

Mineral	Group I *N*	Group I *M*	Group I *SD*	Group II *N*	Group II *M*	Group II *SD*
		Weight per Brain (Mg)				
Phosphorus	40	5 120	.404	71	5.124	.338
Sodium	40	7.781	3.307	39	5 477	1.389
Potassium	37	7 897	.646	39	6.197	2.193
Calcium	40	2 246	.537	71	9.128	1.663
Magnesium				71	.492	.073
		Concentration Scores (Micrograms per 100 gm of fresh brain)				
Phosphorus	40	351.9	36.4	71	315.4	15.9
Sodium	40	538.2	247.2	39	338.7	92.5
Potassium	37	540 9	58.2	39	383.2	138.9
Calcium	40	154 3	38.6	71	564.0	106.2
Magnesium				71	30.3	4.5

In the third place, the reactivity of the several compounds and components in which the content of any mineral is distributed is such that any high relationship between spatial concentration and learning ability should not be expected. It is possible that only a variable per cent of the brain content of these minerals is physiologically reactive, and probably not all of that reactivity is significant for learning. Minerals exist to some extent in insoluble compounds and according to Eaves (8) even in extra-cellular accretions in pathological conditions. Koch and Koch (13) found that in rats previous to 40 days of age there were marked changes from the more reactive to the less reactive forms of phosphorus. Alm and Whitnah (1) found no certain relationship between saturated phospholipids and learning ability whereas the relationship between unsaturated phospholipids and learning ability was considerable. In other words the phosphorus in the saturated compounds did not correlate with learning ability.

These facts seem to agree with Koch and Koch's theory of the organization of organic chemical components. They (13) claimed that, "There is a principle now coming to be generally accepted, namely, that in living matter we are not dealing with an aggregation of more or less similar, highly organized and necessarily complex molecules, but rather, with a more or less heterogeneous substratum in which dissimilar and not necessarily highly complex molecules, or their dissociated particles, are engaged in a series of correlated chemical reactions." From these data it might be inferred that the relationship between any mineral and learning ability will depend upon the reactivity of the compound or components in which it is found. In some compounds it will correlate positively and in others negatively with learning ability. Therefore, the resultant relationship of the total content or concentration of any mineral with higher behavioral adjustments is likely to be low.

In the fourth place, the findings obtained in this study were from normal rats, and may be very different from what would result from experimental and pathological deficiencies and excesses of brain minerals. It is very possible that such extremes might correlate significantly with learning ability in spite of the fact that this study has indicated for four out of five minerals that wide normal variations in content and concentration probably have only a low relationship with learning ability. In view of these findings one should be very cautious about predicting the behavioral effects of normal variations of brain

minerals from behavioral effects produced by experimental and pathological deficiencies and excesses.

G. Conclusions

1. Potassium is related positively to learning ability in rats. Of the five different minerals investigated, it showed the highest and most consistent positive relationship to learning ability. Moreover, the partial correlations are in the main substantially higher than the zero order of correlations.

2. There is probably only a low negative relationship between total brain phosphorus in rats and maze learning ability.

3. The relationship between brain sodium and learning ability in rats is not clear. The data varied with different groups. There is a possible age difference that should be investigated.

4. Magnesium may have a slight positive relationship to learning ability.

5. Brain calcium in normal rats has no clear relationship to learning ability.

6. It is possible that the variations of certain compounds of any mineral are more significant for learning ability than the variations of the total amount of the mineral.

7. Since it is possible that for some minerals the range of content in normal brains is largely above any minimum concentration and below any maximum concentration that might affect learning, it is unsound to predict the effects of normal variations from the effects produced by experimental and pathological deficiencies and excesses.

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Kansas State College
Manhattan, Kansas

The Journal of Genetic Psychology, 1941, **59**, 65-76.

MONTH OF BIRTH AS RELATED TO SOCIO-ECONOMIC STATUS OF PARENTS*

Institute of Child Welfare, University of Minnesota

FLORENCE L. GOODENOUGH

In 1929 Blonsky (1) published an article showing a small superiority in Binet *IQ* of children born during the spring months when compared to those born during other seasons of the year. For a total of 453 children the results were as follows: those born in the spring had a mean *IQ* of 84.3, while the means for the remaining seasons were, summer, 81.5; autumn, 81.3; winter, 80.1. He also found that only 48, or 18.1 per cent, of 265 school repeaters had been born in the spring. The departure from a chance expectancy of 25 per cent is 2.92 times its standard error which is close to the usual criterion ($CR = 3.0$) for "statistical significance." Just what it signifies is, however, questionable, for as Pintner has correctly pointed out (5), the dates at which children are admitted to school and similar policies of school administration may readily operate in such a manner as to bring about systematic differences in the average chronological and mental ages of children in the same grade whose birthdays fall in different months.

In an admitted mood of skepticism as to the validity of these findings, Pintner (5) therefore undertook to test Blonsky's results by means of an examination of the test records of a larger group of New York City school children. The subjects, numbering 4,925 cases, are described as being "of all ages and grades, tested by different group tests, namely the *National Intelligence Test*, Pintner *Rapid Survey*, Terman *Group*, Otis, Haggerty *Delta I* and *Delta II*, Pintner *Non-Language*, Pintner-Cunningham, and *Detroit First Grade*." Obviously the lumping of results from so many different scales into a single distribution is hazardous. Sangren (8) for example has shown that the mental ages and intelligence quotients derived from the Otis, Haggerty *Delta I*, Pintner-Cunningham, and Detroit tests are in no way comparable, either in respect to mean or to standard deviation and that variations in the form of the

*Received in the Editorial Office on April 10, 1940.

distribution of scores when the same group of subjects is tested by each of these scales is a further complicating factor. If, as is likely to have been the case, there was a tendency to use certain tests on one occasion, others on a different occasion, inequalities of standardization alone might easily have operated either to obscure seasonal differences actually existing or to give a spurious appearance of such differences when none were present. Taking the results as they stand, a slight tendency appears in the direction of higher *IQ*'s for children born during the warm months (May to October) as compared to those born during the colder months. Because of the large number of cases, the difference of 1.40 *IQ* points has a critical ratio of 2.66.

A second study by Pintner and Forlano (6) is based upon 17,502 cases, chiefly from New York City, divided on the basis of information supplied by the children into three socio-economic groups, designated as "low," "medium," and "high." Again, a very wide variety of tests was used to obtain the intelligence quotients. Although there are many irregularities in the findings, the general trend is the same as that previously reported. For each of the three social groups separately and for the total, the lowest mean *IQ* was found for the children born during the winter months. The rank order of the seasons when all cases are combined is the same as that reported by Blonsky, viz.: spring, summer, autumn, winter. Again the differences are small, ranging from a mean of 102.35 for those born during the spring to 100.65 for those born in the winter.

A more recent study by Fialkin and Beckman (2) is based upon a sample of 3,189 male adults all of whom were given the Pressey *Senior Classification Tests*. Scores were expressed in terms of half-sigma values with the mean for the general population set at 5.0. Inasmuch as the group tested was superior to the average, the scores obtained had a mean value of 6.61, which, in a more usual notation, would be equivalent to .805 sigma above the general mean. When distributed according to season of birth, the rank-order is the same as that found in the preceding studies listed. The means are as follows: spring, 6.69; summer, 6.66; autumn, 6.58; winter, 6.53. If we attempt to estimate what this difference would become if expressed in terms of intelligence quotient, and assume for this purpose a standard deviation of 16 *IQ* points, the difference between the

means of the spring and winter groups would be 2.56 *IQ* points which corresponds very closely with that found for children.

Recently Pintner and Forlano (7) have published a third study based upon 8,985 children of low *IQ* enrolled in special classes in New York City, 658 institutionalized feebleminded, and several groups totalling 5,121 cases from various parts of the southern hemisphere. Although for all of these cases the seasonal differences are extremely slight, they are in general agreement with previous findings. Feebleminded children in New York City special classes who were born during the winter months rank, on the average, 0.5 *IQ* points lower than those born during the spring. For the number of cases included, this yields a critical ratio of 2.32. The various samples from the southern hemisphere do not show entirely consistent results, but the trend is again toward a slightly higher mean during the southern spring (October-December) and a lower mean during the winter (July-September). The difference, however, is only a small fraction of an *IQ* point.

Although it is obvious that from a practical standpoint, none of these studies has shown enough relationship between season of birth and subsequent intellectual standing to merit serious consideration, the consistency of the findings from one investigation to another indicates that some systematic factor is at work. The most common presumption appears to be that the seasonal differences in *IQ* may be attributable to differential exposure to sunlight during the early months of life, together with the fact that in regions removed from the equator the proportion of ultra-violet rays present during the summer is definitely greater than it is during the winter months. Other hypotheses investigated by Pintner and Forlano include comparison with seasonal differences in infant mortality rates and comparison with weather bureau reports. Their final conclusion as expressed in their latest (1939) article is that "so far, no eminently satisfactory hypothesis has emerged."

It has occurred to me that another and perhaps somewhat simpler explanation than any hitherto proffered may be possible. It is well known that on the average, children whose parents belong to the professional and "white collar" occupational classes make higher scores on standard intelligence tests than do those of the laboring classes. This difference between socio-economic classes is clearly shown in the 1933 study by Pintner and Forlano as well as in

practically all others in which the question has been investigated. There is evidence, too, that the upper social classes are on the whole better acquainted with contraceptive methods than the lower and that the birth of their children is more likely to be a matter of deliberate planning rather than chance. If, then, intelligent parents regard certain months as more desirable for the birth of children than others it is to be expected that a small but real relationship between month of birth and average level of intelligence would appear in an unselected population, not because some months or seasons are more favorable than others for the development of intelligence after the child is born but merely because these seasons include an excess proportion of children from the superior intellectual classes.

As a check upon this hypothesis, the months of birth of 3,275 children whose records were available in the files of the University of Minnesota Institute of Child Welfare were tabulated with reference to the occupation of the parents grouped according to the Institute of Child Welfare Occupational Classification (4). This system of classification, which is based on the data reported in the U. S. census, provides for seven main occupational classes, roughly defined as follows:

Group I. Members of the learned professions.
Group II. Major business executives.
Group III. Office workers, retail owners, and highly skilled workmen.
Group IV. Rural owners.
Group V. Semi-skilled workmen and minor clerical workers.
Group VI. Slightly skilled workers.
Group VII. Day laborers, urban and rural.

This system of classification has been utilized in a number of studies both here and elsewhere. Children from the six urban classes included in this study have uniformly been shown to follow a descending scale in average intelligence.[1]

[1]The original arrangement of the classes included the six urban groups only. When it was later decided to include the farming group a question arose as to where it should be placed. Because of the wide range of intelligence commonly believed to exist within this group, it was tentatively decided to place it at the midpoint of the distribution. It was therefore listed as Class IV. Recent studies, however, indicate that this placement is too high and that in order to preserve the hierarchy the positions of

Inasmuch as our main interest in this study was to ascertain the relationship between month of birth of children and the socio-economic class of their parents we have not made separate computation of the mean *IQ*'s of our cases according to month of birth. Previous studies have agreed in showing that such differences are so small that a very large population is needed in order to establish reliable trends. The greater number of our cases were first tested during the preschool years at which time the available tests are distinctly less reliable than those suitable for use with older children. This would necessitate an even larger population in order to yield dependable results. A greater difficulty is to be found in the fact that since these children were tested in connection with various research projects, the initial test given has not always been the same. For well over half the group, the first test used was the *Minnesota Preschool Scale*. On this test, the mean *IQ* by occupational class for the 900 children comprising the standardization group[2] is as follows: Group I, 109.9; Group II, 107.8; Group III, 104.5; Group V, 99.6; Group VI, 98.2; Group VII, 92.1.

Approximately 450 children were first tested by the Kuhlmann 1922 *Revision of the Binet Scale*. For 380 children reported in an earlier study (3) of this test, the mean *IQ*'s by occupational class were found to be as follows: Group I, 116.1; Group II, 111.7; Group III, 107.7; Group V, 105.3; Group VI, 104.3; Group VII, 96.0.

About 200 children were first tested by means of the 1937 Revision of the Stanford-Binet. In the standardization of this test, the *Minnesota Classification* was used. Terman and Merrill (9) report the relationship to occupational class by ages separately. Following are the means for the age-groups 6-14 years inclusive, which is generally thought to be the range for which the scale is most valid: Group I, 115.2; Group II, 109.7; Group III, 106.3; Group V, 104.0; Group VI, 100.3; Group VII, 96.6.

A smaller number of children were first tested by one or another of the following tests: the 1916 Revision of the Stanford, for which a number of studies have shown a relationship to occupational class

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this group and the present Group V should be interchanged. This does not affect the present study which is based entirely upon an urban population and thus includes no cases classified as Group IV.

[2]Both of these groups of cases are included in the present study, along with others more recently studied.

similar to those reported, and a few either by means of the *Merrill-Palmer Scale* or the *Arthur Scale* of performance tests. Also included in the tabulation are brothers and sisters of tested children when the dates of birth of the latter were known. This group is, however, relatively small.

Table 1 shows the distribution of cases by month of birth and occupational classification of parents.

TABLE 1
DISTRIBUTION OF CASES BY MONTH OF BIRTH AND PATERNAL OCCUPATION

	Occupational class						
	I	II	III	V	VI	VII	Total
January	51	35	57	53	17	24	237
February	57	26	89	54	16	23	265
March	65	65	96	59	24	17	326
April	65	36	95	52	11	18	277
May	69	39	58	55	13	26	260
June	54	36	99	47	14	24	274
July	77	39	96	51	30	21	314
August	63	36	112	58	34	13	316
September	59	42	94	52	29	14	290
October	59	30	99	42	26	19	275
November	62	34	68	41	22	15	242
December	42	31	49	49	15	13	199
Total	723	449	1012	613	251	227	3275

In Table 2 the data from Table 1 have been regrouped according to seasons. Inasmuch as examination of the data in Table 1 shows no differential tendencies for Classes I and II, or among Classes V, VI, and VII, the groups have been condensed into three main classes. The conventional grouping in which December, January, and February are classed as winter months, March, April, and May as spring, June, July, and August as summer, and September, October, and November as fall months has been employed.[3] The percentages

[3]This grouping is slightly different from that employed by Pintner and Forlano, who counted January, February, and March as winter months and so on for the other seasons. Examination of their tables shows, however, that in every case the mean *IQ* found for December is lower than that for March. Inasmuch as infants born in December have to live through an entire cold season before the intervention of warmer weather while those born in March are at the beginning of the spring season, common sense as well as the evidence from the data itself indicates that the conventional classification of March as the first of the spring months is the one to be employed here. Had this rule been followed by Pintner and Forlano, the seasonal differences shown in their data would have become slightly, though not materially, more clear-cut.

TABLE 2
COMPARISON OF THE SEASONAL DISTRIBUTION OF BIRTHS FOR DIFFERENT OCCUPATIONAL GROUPS WITH CHANCE EXPECTANCY

Chance expectancy* (pei cent)	Spring 25.2	Summer 25.2	Autumn 24.9	Winter 24 7
Group I-II				
N	339	305	286	242
Per cent	28.9	26.0	24.4	20.6
Difference	3 7	.8	5	4.1
CR	2.64	.59	.38	3 28
Group III				
N	249	307	261	195
Per cent	24.6	30.3	25.8	19 3
Diffeience	6	5.1	1 0	5.4
CR	.43	3.40	70	4.15
Groups V, VI, VII				
N	275	292	260	264
Per cent	25 2	26.8	23 8	24.2
Diffeience	0	1 6	1.1	.5
CR	0	1.14	79	.45

*Based on a year of 365¼ days with Februaiy counted as 28¼ days.

of the total number of cases in each of the three socio-economic classes and the standard error of the differences between these percentages and chance expectancy according to the number of days in each of the four seasons is also given.

Both for Groups I and II combined and for Gioup III, the pioportion of children who were boin duiing the winter months was found to be smaller by a statistically reliable amount than would be expected if chance alone were responsible. In the case of Groups I and II, this deficiency was counterbalanced by an excess in the number of cases born during the spring while duiing the summer and fall the proportion was not far from that to be expected by chance. In Group III, the highest peicentage of births occurred during the summer while the proportion born during spring and fall was not significantly different from chance expectancy. Within the three lowest occupational groups, however, biiths were about equally divided among the four seasons. In no case was there a reliable departure from the percentage to be expected by chance.

A similai tiend can be observed in the data reported by Pintner and Forlano (7). When the number of cases born in each of the

four seasons within each of their three social groups is computed, the results appear as in Table 2a.

TABLE 2a

	Spring	Summer	Autumn	Winter
Low	1940	1983	1858	1964
Medium	1073	1040	979	1079
High	1447	1415	1400	1324

With the possible exception of the autumn births in the medium group, the only systematic tendency for number of births to fluctuate according to season of the year is to be found in the group of highest social status. For this group, the order for the four seasons is the same as that established for our cases. The differences are not great but the trend is regular, and its direction is in precise accordance with the seasonal differences in intelligence quotient previously reported.

Neither Pintner's system of classification nor the one employed by us can be expected to do more than yield a crude approximation to the intellectual level of the individual parents. We have, however, computed the seasonal differences in *IQ* to be expected for our cases if each child tested exactly at the mean of his occupational class, using the figures previously cited and the distribution of cases by month of birth as summarized in Table 1. The mean difference between seasonal extremes is 0.9 *IQ* points, with children born in the spring ranking highest and those born in the winter lowest. Inasmuch as paternal occupation affords only a rough estimate of parental intelligence which is probably the factor primarily responsible for the relationship found, this estimate almost certainly understates the true difference which might be expected had it been feasible to compute this from the empirical data.

As a further check upon the likelihood that the differential birth rate established for the superior occupational groups has resulted from the deliberate planning of births on the part of these families, the following letter was sent to eight of the leading pediatricians in the city of Minneapolis:

Dear Dr. ———.

Recent investigations appear to show certain differences in the later development of children born during different sea-

> sons of the year. The differences are small and there is much overlapping between groups but the same general trends have appeared in a number of investigations from various northern communities
>
> The question then arises whether these apparent seasonal differences are genuine or whether some special selective factors affecting the sampling of subjects is responsible. As a partial means of throwing light on this question, I am asking a number of leading pediatrists in the Twin Cities whether or not, in their opinion, there is any advantage either to mother or child in selecting certain months for the birth of children.
>
> If you believe that seasonal advantages do exist, however slight they may be, I should greatly appreciate it if you will indicate by marking with a + (plus) sign on the enclosed sheet each of the three months that you regard as the most favorable for having children born in this climate. Mark with a — (minus) sign the three that you regard as the least favorable. If you believe that the month of birth is of no importance for either mother or child, place a check mark before the phrase, "no difference"

Enclosed with this letter was a separate blank listing the 12 months of the year with the two following questions appended:

> *If you think that seasonal advantages exist, please state your reasons here.* (Space allowed for reply)
>
> *Have you ever personally known of instances in which season was taken into account by parents in planning for the birth of children?* (Underline) Yes. No.

Replies were received from seven of the eight physicians with results shown in Table 3.

Finally, the members of a study group conducted under the auspices of the Parent Education Department of the Institute of Child Welfare were asked to state their opinions as to the most desirable season for the birth of children. The group consisted of 33 women from a superior residential district. The questions put to them were the same as those sent to the physicians. The results are summarized in Table 3.

Neither the pediatrists nor the parents followed instructions exactly in filling out the blank. Some marked more or fewer than the specified three months. A large number of the women and one of the doctors failed to mark the months thought least desirable al-

TABLE 3
MONTH PREFERRED BY PEDIATRISTS AND BY MOTHERS FOR THE BIRTH OF CHILDREN

	Pediatrists		Mothers	
	Marked +	Marked —	Marked +	Marked —
January	1	2	1	2
February	2	2	3	2
March	2	1	12	1
April	3		19	
May	4		19	
June	4		9	
July	1	1		1
August		1		1
September		1	2	1
October		1	1	1
November		1		7
December		2		2
No difference	1		7	

though they had marked the ones thought most advantageous. That this was frequently an oversight on their part is indicated by the fact that the reasons given by them for their expressed preferences often included an implicit or even an overt indication of the months to be avoided. The following are examples from women who failed to check non-preferred months.

> *Easier to take advantage of sunshine and fresh air. Less danger of infections—fewer colds.* (Preferred months, April, May, June.)
>
> I believe the months of spring and summer are best in that both mother and child are more apt to avoid infections than during the cold months with little sunshine. (Preferred months, April, May, June)

In spite of these minor irregularities, the trend is clear. December is not mentioned as a "preferred" month by any physician or parent. April, May, and June are likewise never included either specifically or by implication among the months to be avoided. April and May combined account for over 57 per cent of all the "favorable" checkings by the group of parents; with the addition of March and June, almost 90 per cent of the parents' preferences are accounted for.

The reasons given for these preferences may be summarized under three heads: Health of mother and child, including lessened danger

of infections, greater ease of caring for child, lessened discomfort to prospective mother by avoiding the season of very hot weather during the last and "heavy" months of pregnancy.[4]

To the inquiry as to their personal knowledge of instances in which the season had been taken into account in planning for the birth of children, two of the physicians and seven of the women answered "no"; two physicians and seventeen women answered "yes"; three physicians and nine women failed to reply.

All in all, the results of this study appear to indicate that although the mean *IQ*'s of a group of unclassified children may be expected to show small variations according to month of birth, it is unnecessary to postulate any direct environmental effect of the season itself in order to account for these differences. The explanation probably lies in a greater tendency on the part of parents of superior intelligence to arrange for the births of their children to take place during months that they regard as more desirable from the standpoint of their physical well-being. That the spring and summer months are thought to offer some advantage over the winter months in this respect is attested by the statements of Minneapolis pediatrists and a group of educated mothers. Furthermore, that these preferences are not merely idle wishes but that among the upper social and intellectual classes practical means are being taken to bring them into actuality is evident from the data presented on the relative frequency of births in the various seasons of the year within the groups specified. Inasmuch as superior parents are likely to produce superior children, it follows as a matter of necessity that any factor which operates in such a manner as to bring about an unequal selection of children from the various socio-economic classes may be expected to show a relationship to child-intelligence. Such a relationship, however, may be only an artifact of selection. The intellectual differences between children classified on the basis of such a factor do not, of necessity indicate any *ex post facto* result of the factor itself, but may be solely due to some underlying relationship affecting the grouping. The seasonal differences in the intelligence of children classified according to their months of birth appear to be best accounted for on the basis of selective planning of births with refer-

[4]It should perhaps be noted that this preference for the spring months and the accompanying avoidance of the winter season is given definite support by infant mortality statistics.

ence to season on the part of the more intelligent parents, a tendency that is not apparent within the lower social levels.[5]

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Institute of Child Welfare
University of Minnesota
Minneapolis, Minnesota

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[5]It is also possible that seasonal differences in the months preferred for marriage may affect the distribution of birth-months for first-born children. Thus, the traditional June marriage might lead to a slight preponderance of March and April births. I have no direct evidence, other than popular opinion, as to the extent to which seasonal differences in date of marriage varies with socio-economic class, but the 1939 statistics for Hennepin County, Minnesota showed a total of 1,830 marriage licenses issued during the three months of June, August and September which compares with only 751 issued during January, February, and March.

The Journal of Genetic Psychology, 1941, 59, 77-83.

THE RÔLE OF PERSONALITY MALADJUSTMENT IN READING DISABILITY[+]

Teachers College, Columbia University

ARTHUR I. GATES

In their attitude toward the rôle of personality maladjustment in reading disability, specialists in remedial reading could be found at all steps between two extremes. At the one extreme are specialists who think that personality factors and adjustments are so rarely the causes of reading difficulty (although they may often be the result) as to make extensive investigation of personality factors futile. At the other extreme are persons who consider that most, if not all, reading disabilities are merely one symptom of a deep-seated, general maladjustment. According to the former, emotional distress is cured by teaching the child to read; according to the latter, the child's reading defect is cured by removing the emotional distress. Between these extremes are many other views. Some hold that emotional maladjustment and reading defects are concomitants, neither causing the other. Some hold that the one is sometimes cause, sometimes effect, sometimes concomitant.

On scarcely no important professional issue in reading is there more disagreement in theory and practice. No issue is of much greater practical consequence. I wish therefore to report the implications of several studies conducted during recent years by my students and colleagues and myself.

Several years ago, three related Doctoral dissertations were planned in this field. The first by Margaret Ladd (4) was designed to show the differences between good readers and reading detectives in each of a large number of single personality items from personality tests, questionnaires, and inventories. A second by Chester C. Bennett (1) produced a more complete assembly of data concerning each of a smaller number of cases from birth to the date of the study. This study yielded a fairly complete case history. The third study by Jeannette McClure (5) consisted of a definite case study of

[+]Received in the Editorial Office on April 12, 1940

good and poor readers using the techniques of clinical psychology. A fourth study comprises a report by Robert C. Challman (2), specializing in clinical psychology at Teachers College, based on cases studied in the Remedial Reading Clinic by him over a period of two years. A fifth source of data is my own file of cases examined over a period of years (3); a sixth, the studies of Wilson and Flemming (6) of reading progress during the first three grades in Horace Mann School, and the seventh, studies by Guy L. Bond, Russell, and myself, (3) of the first two years of reading by several classes in the public schools of New York City. The eighth source of information is the New York City Remedial Reading Project (7), now beginning its seventh year of activity, an enterprise in which over fifty thousand children have been given remedial instruction.

I shall not report these studies individually, but present my own interpretation of the findings of the series as a whole.

Conclusions Concerning Methods of Study

1. The control group—the matching of the disability with a good reader of essentially the same age, sex, *IQ*, schooling, and home environment—is absolutely essential. Reports based on studies of reading disabilities alone without controls are of limited value because normal readers may and often do reveal all the characteristics found among poor readers except, of course, reading difficulty.

2. The genetic study is superior to the diagnostic. The former consists in making the appraisal before and while the child is learning to read; that is, before the examiner knows which child will succeed and which will fail. In this method, the subtle prejudice of the examiner which may operate when he knows in advance which is a good and which is a poor reader is eliminated or at least reduced. The genetic procedure makes it possible to distinguish cause, effect, and concomitant relationships of personality and emotional factors on the one hand and reading difficulty on the other more reliably.

Conclusions Concerning the Rôle of Personality and Emotional Factors

1. There is no single personality pattern among pupils of adequate intelligence characteristic of the reading failure or disability. Contrariwise, reading disability is found in all sorts of personality types, home backgrounds, parental relationships, and emotional pat-

terns. Some very poor readers declare they like to read, whereas some excellent readers maintain they do not. Some reading failures enjoy their rôle; some are utterly unconcerned about it, although the majority are distressed by it. Here is a child with an *IQ* of 125, with the highest score in his class in three reading readiness tests, without physical or sensory defects, with a fine home and excellent parental management, real interest in learning and an excellent teacher. He apparently had everything, but he failed to learn to read. Here is another child with an *IQ* of 80 and a mental age eight months below the average of his class, from a destitute home, suffering from malnutrition and neglect; with a dull, ailing, nagging mother, an alcoholic father, an imbecile brother. This boy was nearly blind from tuberculosis in one eye; he was a nervous, tense child taught in a class of 45 pupils by a poor teacher. He had nothing; but he learned to read very well, earning a Reading Quotient of 120 at the end of his first year. These are exceptional cases but they are numerous enough to upset any simply formulated rule.

2. The good readers are consistently superior to the poor in almost no single personality or emotional trait or experience or misfortune. The inventory of single personality traits, or interests or home background items is of little value in predicting or explaining success or failure in reading. Bennett, Ladd, and Wilson lined up hundreds of single items—varying from the time of the first tooth, whether grandmother smoked a pipe, to tests and ratings of introversion, dominance, nervousness, etc.,—on practically none of which could one distinguish a whole group of poor readers from a group of good readers.

3. Patterns of personality or other traits secured by statistical analysis have, in my opinion, yielded little of value. In other words, combinations of traits secured by additions and subtractions of single items do not seem to be very illuminating.

4. Emotional or motivational or dynamic patterns have been revealed by clinical analysis, which, in certain cases, undoubtedly comprise at least a partial cause of reading difficulty. In these cases, the child's dynamic pattern of conduct and purposes is one which produces emotional resistance to learning to read. To illustrate: A boy was sent to a particular progressive school on the insistence of the mother and despite the opposition of the father, who predicted the boy would get no good out of the new fangled institution. The

mother nagged the boy to do well; the father appeared delighted when he did poorly. The boy became the center of conflict. The father once asked the boy to read a Primer. Being in a "reading readiness stage" in school, the boy, like others in his class, was unable to read the book. The father was really delighted. The boy, anxious for his father's approval, made the mental adjustment which produced resistance to learning to read. When the examiner got all understood and forgiven, the boy learned to read rapidly and well.

5. These blockings and resistances arise from conditions or episodes in the school, in the home, in relations of parents and teachers, and in other ways and elsewhere. Among the situations uncovered in the studies mentioned above were the following:

a. Apparent indifference of teacher or parents to the child's welfare, often resulting in feelings of insecurity or neglect.

b. Apparent hostility of teacher or parents suggested by scoldings, predictions of failure, etc.

c. Apparent anxiety of teacher or parents suggested by constant inquiry or supervision or excitement.

d. Over-protection of child by parents; helping the youngster so much that he learns to do little by himself.

e. Apparent conflict in purpose or desire between parents or between parents and teacher.

f. Conflicting desires of pupil due to sibling rivalry, or rivalry with other children.

g. Persisting emotional tensions resulting from the embarrassment or ridicule attending a failure in oral reading, recitations, tests, etc.

This list illustrates the types of situations which appear to lead to emotional tension, anxiety, fear or resistance which, in turn, interferes with learning to read. It thus appears that in certain cases reading disability may be caused by personality maladjustment.

6. The experiences and studies from which this conclusion is drawn tend, on the whole, to show, however, that personality maladjustment of these types is a comparatively rare cause of serious reading defect. One of the investigators estimates that in those cases in which personality maladjustment is clearly present, it is the cause, rather than an independent concomitant or a result of reading defect, in one case in ten, another estimates two in ten.

It is important to note, moreover, that any of the alleged causes

such as parental neglect or sibling rivalry does not always—indeed only rarely—leads to reading defect. The cause is really a stimulus-response unity. Reading defect arises not when the teacher ridicules the child's errors in oral reading, but only when the child is badly and persistently upset in some way by the teacher's ridicule.

7. A given kind of "cause" moreover may sometimes have exactly the opposite effect. Instead of producing reading failure it may produce reading excellence. For example, in one case observed a boy developed resistance to reading from sibling rivalry. He refused to compete in reading when he found that his sister was being praised for her progress in the art. In another case, a boy redoubled his efforts and became an exceptional reader when he found that his younger brother was rapidly learning to read. In all these cases, the primary matter is the character which a pupil's adjustment to a vital situation may take. Often the pupil's adjustment to the situation may be rationalized by himself. It becomes a guiding principle, or a tenet of his philosophy. He may say, *"I won't do anything that that girl likes to do,"* or, *"I'll do better than Bill if it kills me."* In other cases there may be only a dynamic trend which the pupil scarcely appreciates. In any case, considerable clinical insight may be needed to uncover the vital factor.

8. Maladjustments found in reading disability cases are of numerous forms. Challman lists the following among cases studied by him:

a. Nervousness—revealed by restlessness, squirming, etc., and unusual irritability or silliness.

b. Withdrawal or "leaving the field" as shown by truancy or daydreaming, etc.

c Aggression—"trying to get the teacher's goat," exercising cruelty or bullying on other pupils.

d. Defeatism—discouragement, hopelessness, inferiority feelings.

e. Chronic worry—tense or fearful worrying about failure in an oral reading lesson, in tests, etc.

9. All of these symptoms or forms appear among cases in which the maladjustment is the cause, the result or the concomitant of reading difficulty. It is therefore not possible to tell by the personality symptoms whether they were causes or effects or an accompaniment of trouble with reading.

When the personality maladjustment is truly a cause of the reading difficulty, discovery, understanding, and treatment of the maladjustment are helpful and perhaps often indispensible. In some cases very skillful management of the child may result in reorienting him toward reading in such a way as to lead to success in learning to read without the basal factors having been discovered. This explains why some specialists feel that the clinical analysis is unnecessary. Probably in all such cases clinical insight combined with skillful management is better than the latter alone and in some cases it is likely that the insight is essential to good management and hence to correction of the reading difficulty. At the same time, there is evidence that the clinical insight and skillful general management combined are not always enough to secure the optimum improvement in reading. A period of reading difficulty, however caused, may stamp in disinterests and inappropriate techniques until they can be dislodged only by skillful guidance and instruction in the specific techniques of reading.

The reverse is likely to be true. When personality maladjustment is the result of failure in reading per se, it will usually disappear without special treatment if a clever teacher succeeds in teaching the pupil to read. Occasionally, however, the resulting emotional or general maladjustment produced by reading failure becomes so well established as to require specific treatment after the pupil has learned to read. In general, then, it appears that the techniques of clinical study and the techniques of analysis of reading difficulties per se combined are more useful in dealing with cases where maladjustment is cause, effect, or concomitant, than either alone.

10. From what has been said, it should not be concluded that personality maladjustments or emotional tensions appear in all cases of reading difficulty or even in all cases of very serious disability or failure. Challman reports that he found no such symptoms in at least a quarter of the serious cases referred to the Clinic. When they examined all the retarded readers in a school, both Ladd and Bennett and the author found the number showing maladjustments in excess of those found among the good readers to represent a very small percentage. Those usually sent to clinics are probably predominantly the pupils who show both reading difficulty and maladjustment.

In conclusion, it may be said that personality maladjustment is frequently found to coexist with reading disability. The more serious the reading retardation, the greater is the probability that

maladjustment also exists. My estimate is that among cases of very marked specific reading disability, about 75 per cent will show personality maladjustment. Of these, the personality maladjustment is the cause of the reading defect in a quarter of the cases and an accompaniment or result in three-quarters. For the more serious cases, therefore, a skillful clinical study of the pupil's adjustment is advisable and in some of them general therapy as well as remedial instruction will be needed This group, however, probably forms a relatively small percentage of the poor readers in a typical school. On the basis of experiences with the *W.P.A.* remedial project in New York City, I feel confident that typical teachers can learn to handle at least 90 per cent of the reading defect cases in our schools. For the remaining 10 per cent, which would represent about two per cent of the entire elementary school population, more expert diagnosis and remediation are desirable. It is important that teachers recognize these cases. What is more important, teachers now can and should prevent the development of serious reading disabilities by taking preventive measures before either defective reading habits or personality maladjustments become established.

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Teachers College
Columbia University
New York City

The Journal of Genetic Psychology, 1941, 59, 85-99.

AUDITORY-MOTOR ORGANIZATION IN TWO CLINICAL TYPES OF MENTALLY DEFICIENT CHILDREN[*]

Wayne County Training School, Northville, Michigan

HEINZ WERNER AND MABEL BOWERS[1]

A. INTRODUCTION

It has previously been shown that two types of mental deficiency, the "endogenous" and the "exogenous," differ in visuo-motor organization (5). To the endogenous type of mental retardation belong children in whose families mental deficiency occurs and who do not show signs of a brain lesion. Children whose mental retardation is due to a brain defect are of the exogenous type. On a visuo-motor test consisting of the reproduction of mosaic figures built with marbles the children of these two types make characteristically different errors. Most of the errors of the endogenous type are due to "globalisation." That is, these children simplify the original pattern, make it more unitary, symmetrical, etc. Their procedure is well-rounded and continuous. The exogenous type, on the other hand, frequently build definitely disorganized forms; his procedure is erratic, incoherent.

These results lead one to ask whether he is dealing with a *general* difference of sensori-motor activity. The difference might be due to a specific deficiency of the exogenous type in the visual or visuo-motor field. We have already presented evidence that a specific visual factor does not account for the different behavior on visuo-motor tasks. On mainly visual tests (tests of visual abstraction, analysis, synthesis) no marked differences between the two types have been found. We have, however, not offered experimental evidence of more than a specific difference in one sensori-motor function. For an attack on this problem the investigator must turn to an activity not involving visuo-motor functions.

[*]Received in the Editorial Office on April 18, 1940.

[1]We are indebted to Dr. Alfred A. Strauss, Research Psychiatrist, who made the clinical diagnosis of the children; to Dr Betty Martinson, Research Associate, for her reading of the manuscript; and to Dr Newell C. Kephart, Mental Hygienist, for valuable suggestions.

The present study is an attempt to analyze the auditory-motor performance of the two clinical types. The children, for this experiment, were selected on the basis of two criteria: (*a*) average singing ability, as judged by the music teacher; (*b*) clinical characteristics permitting definite classification as exogenous or endogenous.

Two groups of children were thus selected for the experiment. The one group consisted of 22 children of the endogenous type of mental deficiency. The other group included 26 children of the exogenous type. The groups were quite similar in *IQ* and *MA*. In the endogenous group the average *MA* was 7 years, 8 months, the range from 6 years, 4 months to 10 years, 11 months; the average *IQ* was 64 (range: 50-81). The *MA* of the exogenous group was 7 years, 9 months, the range from 6 years, 2 months to 10 years; the *IQ* was 63 (range: 50-84).

The test consisted of 17 melodic patterns varying in difficulty. Each pattern was played on the piano and the child was requested to reproduce it vocally. The patterns were chosen from a series of musical phrases which Brehmer (1) employed in a study of the melodic ability of normal children. Brehmer examined 60 children ranging from 6 to 13 years of age.[2] The experiment was repeated by the authors with 30 normal children, 6 to 10 years of age, at the University of Michigan. We are thus able to compare the performance of the mentally deficient with that of normal children of the same mental age. The 17 melodic patterns are presented in Figure 1.

A comparison of the achievement of the two groups reveals that the exogenous group is somewhat inferior to the endogenous. Whereas the children of the endogenous type sing 72 per cent of the (374) patterns incorrectly, the exogenous group makes errors in 83 per cent of the (442) patterns. The single patterns, as already stated, vary in difficulty, the motifs given first being easier than those presented later. Table 1 shows the average percentage of errors made on each pattern by the normal, the endogenous, and the exogenous group.

The groups are further divided into two mental age levels, one 6 years to 7 years, 11 months; the other 8 to 10 years. Since statis-

[2]This study was carried out under the direction of the senior author at the psychological laboratory of the University of Hamburg

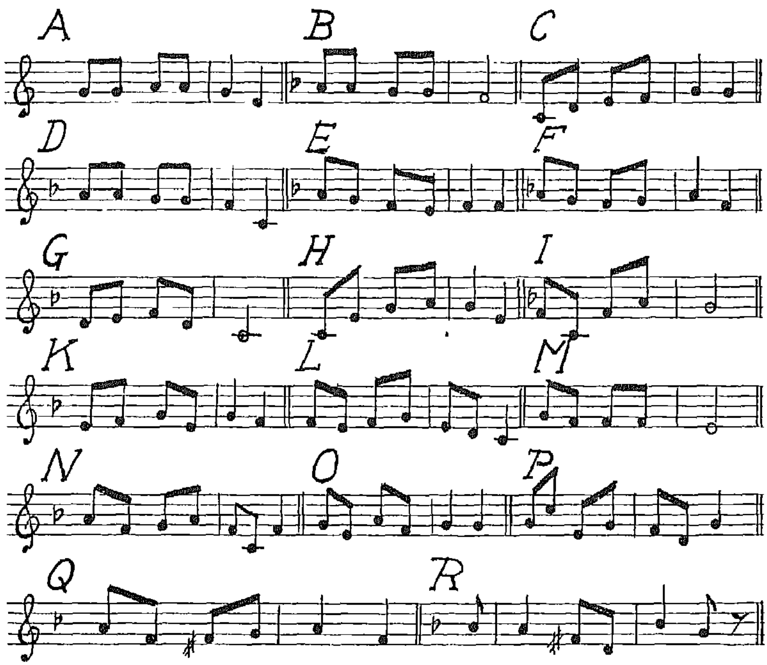

FIGURE 1
SEVENTEEN MELODIC PATTERNS

TABLE 1
PERCENTAGE OF INCORRECT PATTERNS WITH RESPECT TO *MA*

MA. 6-7 11 *N*	End	Exog.	*MA* · 8-10 *N*	End	Exog.
A — 12%	14%	50%	6%	17%	54%
B — 24	22	60	12	14	56
C — 45	54	50	38	38	70
D — 45	54	80	42	50	54
E — 46	54	67	21	17	84
F — 62	70	75	53	74	76
G — 73	70	92	58	62	84
H — 55	62	92	55	62	75
J — 65	62	75	65	74	84
K — 85	93	80	80	86	76
L — 80	85	92	85	86	84
M — 84	100	92	74	74	84

tically reliable data concerning the single motifs sung by normal children are available only on patterns *A* to *M*, only these are used for the computation of Table 1.

Three characteristics of the relative achievement of the three groups are demonstrated by the data: (*a*) the exogenous group, as compared with the normal and the endogenous, makes a greater proportion of errors on the easiest tests, i.e., *A* and *B*; (*b*) On the average the children of the normal and the endogenous group show a noticeable improvement with increasing age whereas the children of the exogenous group improve little; (*c*) If the single patterns are ranked according to their difficulty the rank order for the endogenous resembles that of the normal group more closely than either resembles that of the exogenous group. The rank order correlations are given in Table 2.

TABLE 2
RANK ORDER CORRELATIONS WITH RESPECT TO DIFFICULTY OF PATTERN

		PE	*D/PE diff*
Normal-Endogenous	+.95	.02	
Normal-Exogenous	+.73	.13	16.9

The coefficients of correlation are therefore reliable and the difference between them is statistically significant.

These results show that the singing performance of children of the endogenous type resembles the performance of normal children more closely than does the performance of the exogenous group. The meaning of this statement will be made clearer by the qualitative analysis of the melodic patterns sung by the children.

In order to find the necessary cues for this comparative analysis we turn first to Brehmer's and our own earlier work on melodic patterns produced by normal children. Brehmer has found that the errors which the children make in repeating the melodic forms show definite trends. In most instances they can be interpreted as a strong tendency to organize the patterns in a more child-like manner. If a normal child is faced with the task of organizing a sensori-motor pattern too difficult for him he will usually retrogress not to chaos but to a more primitive organization, that is, an organization corresponding more closely to his age level. Errors therefore reveal a shift toward a more child-like organization.

The difficulty of the melody does not depend altogether on the number of different notes used in its construction but largely on the configuration of these notes. Motif *E*, for instance, is reproduced incorrectly by 46 per cent of the children between the ages 6 to 9, and by 21 per cent of children ages 10 to 12. On Motif *M*, seemingly no more complicated, errors appear in the record of 84 per cent of the younger children and 74 per cent of the older. By an analysis of the frequency of the different types of errors one gains some insight into the reasons for the relative difficulty of Motif *M*. Tabulation of the types of errors according to frequency shows that Motif *M* is most often changed into the patterns or similar patterns shown in Figure 2, *a* and *b*.
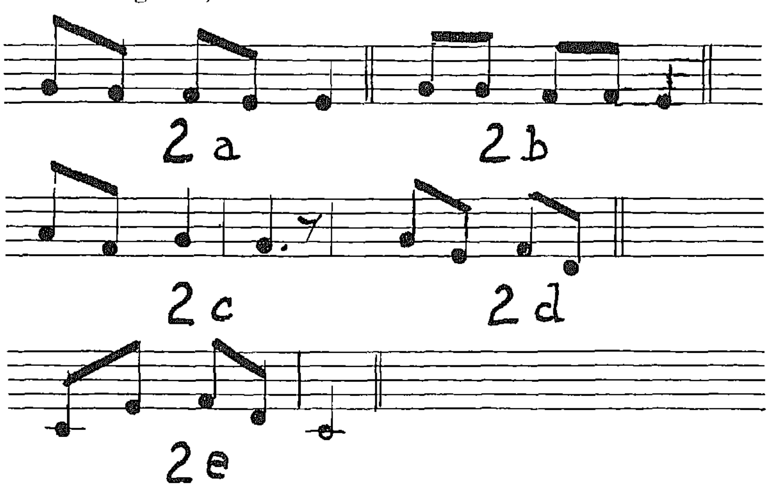
FIGURE 2
TYPICAL CHILD-LIKE CHANGES OF ORIGINAL MOTIFS
M (2*a*, *b*), *N* (2*c*), *O* (2*d*), AND *G* (2*e*)

The first measure of Motif *E* is made up of two pairs of notes both descending on the scale. In Motif *M*, however, the one pair of notes descends and the two notes of the other pair are identical. This complexity seems one reason why Motif *M* is more difficult than Motif *E*. The child attempts to avoid the difficulty either by causing the two notes of both pairs to descend (*a*), or to remain at the same level (*b*). In both cases the two pairs become

more alike in structure. In other words, an equalization of the two parts results in a pattern more homogeneous than the original. The trend toward homogeneity is a typical child-like change. In general, the more homogeneous the structure the more primitive it is.

We shall review briefly some of the pattern changes found in previous investigations to be typical of normal children. Most of these demonstrate a tendency toward primitive organization. The discussion will facilitate the interpretation, from a genetic point of view, of the errors made by the mentally deficient children.

B. Direction of Melodic Movement

1. *Item 1: Simplification of Direction*

A natural way to change a complicated melody into a more primitive one is to reduce the number of changes of direction. Such a change of Motif *N* is illustrated in Figure 2, *c*.

2. *Item 2: Primitivation of Direction*

In a study on the melodic development in the creative singing of 2- to 5-year old children we demonstrated that genetically the earliest direction is downward; the next higher form is ascending-descending. A continually ascending motif appears much later. The latest type of melodic movement is descending-ascending. This type does not appear at all with the young normal children we examined (3, 4). In a later work Nestele (2), using both younger and older children, corroborated these facts. The descending-ascending movement did not occur before the age of 7 years and appeared infrequently at all age levels. These forms may therefore be ranked as follows: descending-ascending, ascending, ascending-descending, descending; and primitivation may be said to occur whenever a pattern of a given direction is changed to a form lower in the developmental scale.

C. Relationship of Tones

1. *Item 3*

Another child-like change is based on a *tendency toward continuity*. In very young children one finds the extreme form of a continuous tonal line in the so-called "*glissando*," that is, the gliding

tone. The glissando disappears with older children, but a marked inclination to increase the continuity of the original pattern remains in the event of large tonal intervals. The gaps tend to be filled by intermediary tones (seldom less than a whole-tone).

2. *Item 4*

Related to Item 3 is another characteristic which we may call the *"levelling tendency."* Children often decrease the size of a large interval instead of filling it with intermediary tones

3. *Item 5*

The levelling tendency is partially responsible for another primitive characteristic of children's singing, viz., the tendency toward a *decrease of the pitch range.* The range is the interval between the highest and the lowest tones of a given pattern.

4. *Item 6*

Another change consists in a decrease in the variety of notes. This will be referred to as the *"trend toward homogeneity."*

5. *Item 7*

Older children especially tend to simplify the notes in a melodic-harmonic sense. They will, for instance, substitute a major or minor third for a whole-tone, or a fifth for a fourth, etc. This trend will be called the *tendency toward harmonic simplification.*

D. Relationship of Melodic Parts

1. *Item 8*

Paralleling the tendency to decrease the variety of notes is a tendency to simplify the structure of the total pattern by decreasing the variety of smaller units and by increasing the similarity of these units to the whole. This trend we shall call "tendency toward assimilation of parts." For example, in Motif *O* (first measure), the smaller units descend but the main direction is ascending. The trend toward assimilation, therefore is expressed when the smaller units are made similar to the total or vice versa (Figure 2, *d*). There are several other examples of assimilation which are included under this item.

2. *Item 9*

As a last characteristic of child-like melodic patterns we may mention the *"trend toward symmetry."* Symmetrization of ascending and descending parts frequently occurs when the original pattern is "asymmetrical." For instance, Motif *G*, changed according tc this trend, appears as presented in Figure 2, *e*.

To summarize: These nine trends seem to explain the majority of changes which a child is likely to make in repeating a melody difficult for him to sing. Each of these trends, viz., simplification and primitivation of direction, continuation, levelling, decrease of tonal range, homogenization, harmonic simplification, assimilation, and symmetrization can be interpreted fundamentally as an effort of the child to organize sensori-motor patterns in accord with his own limited abilities. These items, however, do not explain all the data obtained from mentally deficient children. They make many changes which are contrary to such a genetic interpretation.

The following items, in many cases the opposite of those listed above, had to be added:

3. *Item 10*

Complication of direction of melodic movement. Contrary to the change defined in Item 1, a child may imitate a relatively simple motif by a more complicated pattern.

4. *Item 11*

Instead of retrogressing toward a more primitive pattern the child imitating a difficult melody may produce a melodic movement less primitive than the original. We may call this change *"reversal"* of the genetic sequence.

5. *Item 12*

"Ascending form." Sometimes our children reproduce a melodic pattern as a simple ascending succession of notes. Since such a reproduction is rarely found with normal children we may regard it as a special form of reversal.

6. *Item 13*

"Jump interval." An interval may be increased in size. This trend is, of course, contrary to the normal child-like tendency to decrease the intervals ("levelling").

7. *Item 14*

"Increase of range." This item refers to a non-genetic trend to increase the range of tone in any given pattern.

8. *Item 15*

The reproduction of the original pattern may lack closure, or harmonic and melodic meaning. We shall refer to this characteristic as a *"lack of completeness or congruity."*

9. *Item 16*

This item defines reproduced motifs which have no apparent relation to the original. We refer to such reproductions as *"unrelated."*

E. Qualitative Results

In Table 3 the changes have been computed for each of the 16

TABLE 3
PERFORMANCE OF THE TWO GROUPS IN TERMS OF ITEMS

	Endogenous		Exogenous		
	M	*SD*	*M*	*SD*	D/σ_{Diff}
1. Simplification	45 %	11.5%	23 %	9 4%	5.8
2 Primitivation	45	14	20	10.4	5.6
3. Continuation	23	8 5	7	4 0	6 7
4. Levelling	19	7.8	3	3.2	7.3
5. Decreased range	33	12.5	20.9	10.4	3 0
6. Homogenization	34	10 5	20	9 3	4.0
7. Harmon. simplification	18	7.9	5.6	6 0	5.0
8. Assimilation	21	8.7	6.8	6.6	5.1
9. Symmetrization	14	7 5	6.0	3.8	3 7
10. Complication	0 4	0 7	8.1	8 3	4.1
11. Reversal	1 3	2.4	13.1	7.3	6 2
12. Ascending form	5.5	6 4	13.1	9.0	2.8
13 Jump interval	2.7	4.1	17.1	9.1	6.0
14. Increased range	3.8	5.8	10 4	7.4	2.9
15. Lack of completeness	0.5	1 0	24 4	15.0	6 7
16. Unrelated	3.4	4 8	33.5	23.5	5.3

items. The percentage of incorrectly reproduced patterns in which each type of error occurred was computed for each child. For example, a child may have reproduced 14 of 17 patterns of the test incorrectly; if errors of primitivation occur in 7 of these 14, levelling errors in 6, and errors of assimilation in 6, the respective percentages are 50, 43.7, and 43.7.

The tables demonstrate that changes in terms of Items 1 to 9 occur far more frequently (2 to 6 times as often) with the endogenous than with the exogenous group. The critical ratios indicate that the differences between the performances of the two groups are statistically significant.

The ratios of occurrence of Items 1 to 9 in the two groups are given in Table 4.

TABLE 4

Types of errors	Endogenous	:	Exogenous
Simplification	100	:	51
Primitivation	100	:	44
Continuation	100	:	30
Symmetrization	100	:	43
Homogenization	100	:	59
Levelling	100	:	16
Decreased range	100	:	70
Harmon simplification	100	:	31
Assimilation	100	:	31

On the other hand, changes in terms of Items 10 to 16 occur up to 50 times as often with the exogenous as with the endogenous group. Here again, the differences are statistically significant (Table 5). From these results one may conclude that the auditory-motor performances of the two groups are characteristically different. The endogenous group organizes melodic patterns in ways which can be explained by the facts and laws of normal genetic development. The exogenous group performs to a great extent in a manner which deviates from genetically known forms of organization.

TABLE 5

Types of errors	Endogenous	:	Exogenous
Complication	5	:	100
Reversal	10	:	100
Ascendance	42	:	100
Jump interval	12	:	100
Increased range	36	:	100
Lack of completeness	2	:	100
Unrelated	10	:	100

These results are perhaps even more striking if the two groups are compared not in terms of *items* but of *patterns*. Here we dis-

tinguish two kinds of incorrect patterns. Those patterns which show only changes in accord with genetic laws (Items 1-9) we shall call *A*-patterns. Those which show some peculiar changes not explainable from normal developmental facts (Items 10-16) we shall call *X*-patterns. Figure 3 shows the percentage distribution of the number of children of both groups in relation to the number of *X*-patterns (solid line: children of the endogenous type; dotted line: children of the exogenous type). Fifty-four per cent of the children of the endogenous group do not show one single *X*-pattern. Twenty of the 22 members of this group, more than 90 per cent, have 0 to 3 *X*-patterns. Only two, or 9 per cent, have a greater number of *X*-patterns. On the other hand, only one of 26 children of the exogenous group responded entirely with *A*-patterns. Five of these children showed 0 to 3 *X*-patterns, while the remainder, more than 80 per cent, show 4 to 15 *X*-patterns (Figure 3).

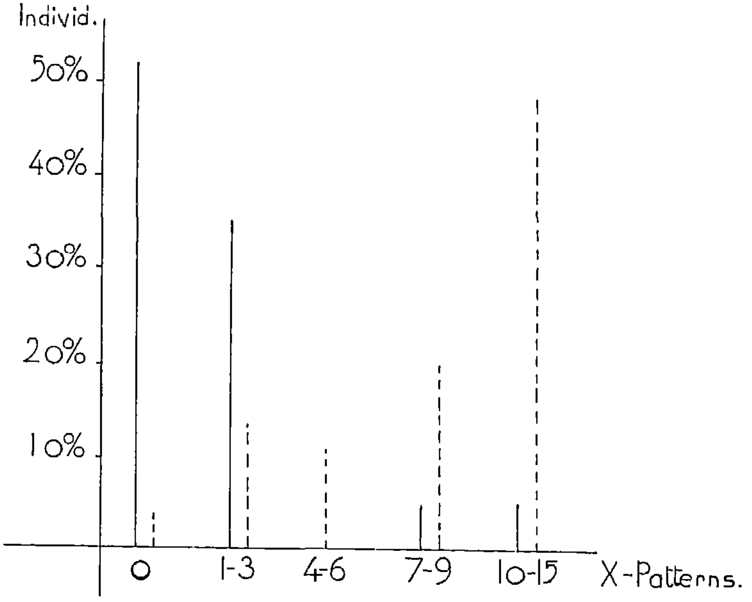

FIGURE 3
PERCENTAGE DISTRIBUTION OF INDIVIDUALS WITH RESPECT TO *X*-PATTERNS
Solid line. endogenous; dotted line: exogenous type.

Furthermore the group performance has been analyzed in terms of the percentage of *A*- and *X*-patterns comprising the total of incorrect patterns (Table 6).

TABLE 6

	Endogenous	Exogenous
Patterns sung by the group	374	442
Incorrect patterns	269	367
% incorrect patterns	72%	83%
A-patterns	238	144
X-patterns	31	223
% *A*-patterns	*88.5%*	*39%*
% *X*-patterns	*11.5%*	*61%*

The difference between the percentage of *X*-patterns of the two groups is statistically significant, the critical ratio being above 7.0.

F. Discussion

It has been shown that two clinically defined groups of mentally deficient children respond differently to the task of singing relatively difficult melodic patterns. The endogenous child usually responds in a manner similar to that of normal children. That is, if he cannot master a complex task, he will usually retreat to a simpler, more primitive form of organization. The exogenous child responds altogether differently. Though his errors are often in the direction of primitive organization, changes in melodic patterns of a type not known in normal development are predominant.

These facts recall the results of the earlier analysis of the visuo-motor performance. Essentially, the results are very similar in both investigations. In visuo-motor as well as in auditory-motor tasks the errors of the endogenous type may be explained by the genetic law of regression to a more primitive level of normal development. The typical errors of the exogenous type are of another order. The combined results of the two investigations seem to permit the statement that the difference in performance is not due to a deficiency in a specific sensori-motor field, auditory or visual. It seems to be based on a much more general factor, inter-sensorial in nature. We may speak of a sensori-motor syndrome characterizing the exogenous type.

The results of the two experiments may be compared in greater

detail. There are, first, common characteristics of the primitive organization to which the child retrogresses if he cannot master the more complicated patterns. In a primitive organization, globality, the "quality-of-the-whole," predominates, and the parts appear more or less alike. A round movement is more primitive than one which is articulated, a circle more primitive than a rectangle. In children's drawings round forms are developed prior to rectangular ones. A circle with its continuity and homogeneity of parts is probably the most striking illustration of globality. Practically, all of the changes of the first nine types (Items 1-9) can be interpreted as a child-like trend toward greater globality, roundness, homogeneity. This global trend is operative whether a child rounds up the corners of a square or fills the large intervals of a melodic pattern with intermediate tones. It is apparent in the tendency to make different parts of the drawings alike as well as in the equalization of parts of the melodies or in the symmetrization of melodic patterns.

On the other hand, we have demonstrated that the visuo-motor performances of the exogenous type are characterized by incoherent procedures, jumps, imperfectly closed and meaningless figures. These typical errors seem to be related to characteristics of the melodic performance of the exogenous type such as jump intervals, unclosed, melodically or harmonically meaningless forms, etc. It seems especially significant that the exogenous type, in contradistinction to the endogenous and the normal, fails frequently on the two first patterns, which are the most primitively organized ones. In the normal, endogenous, and exogenous groups 6, 17, and 54 per cent respectively made errors in Pattern *A*, and 12, 14, and 56 per cent respectively made errors in Pattern *B*.

It is further illuminating to compare the frequency ratio of the occurrence of apparently opposite items (Table 7).

TABLE 7

	Endogenous	Exogenous
Simplification : Complication	45 : 0.4	23 : 8.1
Primitivation : Reversal	45 : 1.3	20 : 13.1
Levelling : Jump interval	19 : 2.7	*3* : *17.1*
Continuation : Jump interval	23 : 2.7	7 : 17.1
Decreased : Increased range	33 : 3.8	20.9 : 10.4
Symmetrization : Lack of completeness	14 : 0.5	*6* : *24.4*
Harmon. Simplification : Lack of completeness	18 : 0.5	*5.6* : *24.4*

The table shows that, in the exogenous group, the two items of jump intervals and lack of closure and meaning, occur far more frequently than the opposite reactions, viz., levelling, continuation, symmetrization, and melodic-harmonic simplification. The predominance in these two items seems particularly significant in view of the fact that they are definitely related to the symptoms found in the performance on the visuo-motor tests.

A secondary experiment, in which the 26 exogenous children were retested on the same patterns after an interval of three months, offers evidence on two points. The general results of the second test are very similar to those of the first test, the number of correct patterns being almost identical, and the changes in pattern being of the same type (Items 9-16). However, there was little tendency to repeat an identical error in a given pattern. This latter fact would indicate that the incoherence typical of the responses of exogenous children is based on a general auditory-motor factor rather than a number of auditory-motor factors appearing in response to specific melodic patterns.

G. Summary

Twenty-two mentally deficient children of the endogenous type and 26 children of the exogenous type were tested on their ability to reproduce 17 melodic patterns. The endogenous type responded in a manner similar to that of normal children. The errors made by this group can be interpreted as a retrogression to a simpler, more primitive organization. The errors of the exogenous type are of a kind not known in normal development. The trend toward globality and the incoherent procedure found in this study to characterize the auditory-motor performance of the endogenous and the exogenous type, respectively, correspond to characteristics found previously in the visuo-motor performances of the two groups. The factors responsible for these differences may therefore be assumed to be intersensorial in nature.

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Wayne County Training School
Northville, Michigan

The Journal of Genetic Psychology, 1941, **59**, 101-107

AN ANALYSIS OF TEACHERS' JUDGMENTS OF PROBLEM CHILDREN*

George Peabody College for Teachers

LEON J. EPSTEIN

Education at the present time is turning serious attention to preparing the child to meet adequately the varied problematic situations he is to face both during his school life and his after-school existence. Stress is being placed upon the social and emotional development of children along with their intellectual and physical training. The relationship of the behavior disorders of children to adult social problems shows the necessity of investigation into the behavior difficulties in the elementary and secondary schools.

It is indeed difficult to define "behavior problem" in terms of personal and social attitudes. Standards of behavior evaluation which would enable us to establish criteria capable of widespread use are lacking. What is acceptable behavior to one parent, teacher, or school system may become unacceptable when the child moves out of their sphere of control. In the field of education, in so far as teachers and administrators possess varied backgrounds and constitutions, there will be differences in the requirements they impose on and the responses they make to the behavior of children.

The purpose of this study was to investigate the extent to which teachers concur in the selection of their problem students and in the assignment of behavioral traits to the children so designated. The subjects of this investigation were the teachers and students of the junior and senior high school grades of a Nashville, Tennessee, public high school. Each teacher of this school was requested to select those children in any of her classes whom she considered to be problem cases. The data to be supplied for each child included name, grade, sex, and the indication on a comprehensive check list of those characteristics which caused the child to be regarded as a problem. Ample space was also provided for the notation by the teacher of problem characteristics which were not cited in the check list.

*Received in the Editorial Office on April 23, 1940.

Three weeks later the name of every child who had been designated as a behavior problem was given to each of his teachers who, on the first check list, had not considered him a problem. The teacher, not informed of the fact that the child already had been selected as a problem by one or more of his other teachers, was requested to rate the child, indicating on a more complete and inclusive inventory than was used previously, the traits and characteristics which applied to him.

The high school which served as the locus of this investigation had a population of 750 students and a faculty of 28 teachers, 24 female and four male teachers. Two female teachers were ill and could not be reached and four female teachers and one male teacher stated that they had no problem students in any of their classes. The remaining 18 female teachers and three male teachers had 118 problem students. This number included four children whose names were reported by three teachers, 15 children whose names were reported by two teachers, and 76 children whose names were reported but once. The names of 95 different children, 12.7 per cent of the total school population, were selected as problems by one or more of their teachers. This figure is higher than the two per cent obtained by McClure (4) and the seven per cent found by Wickman (5). Among the children designated as problems in this investigation, however, many may be termed minor problems, a category in which Wickman includes 42 per cent of his school's population.

Of the 118 children reported as school problems 83 were males and 35 females. This figure of 70.4 per cent males is slightly lower than the 83.3 per cent found by McClure (4), the 74.5 per cent by Boynton (2), and the 76.7 per cent by Wickman (5). The present study, however, was made in the secondary school, and Hildreth's (3) data indicate a decrease in the percentage of male problem children when a high school rather than an elementary school population is considered. It is noteworthy, however, that Hildreth's data are based upon 39 high school children of superior intelligence and economic background.

The causes for the teachers' assignment of a problem rating as observed in this analysis closely agree with those recorded in studies made by Yourman (6), Blanchard (1), Boynton (2), McClure (4), and Wickman (5). A list of these problem traits, the frequency with which each appeared, and the percentage of children

TABLE 1

EXTENT AND PER CENT OF INCIDENCE OF CHECK LIST CHARACTERISTICS AMONG 118 CASES DESIGNATED AS PROBLEMS BY THEIR TEACHERS

Characteristic	Freq.	Per cent	Characteristic	Freq.	Per cent
1. Lack of interest in work	45	38.14	31. Stubbornness	3	2.54
2. Inattention	40	33.90	32. Too easily frightened	3	2.54
3. Will not study	40	33.90	33. Truancy	3	2.54
4. Irregular school attendance	32	27.12	34. Dishonesty, in general	2	1.69
5. Laziness	30	25.42	35. Disobedient	2	1.69
6. Quitter type, no persistence	26	22.03	36. Domineering type	2	1.69
7. Dull mentally and sluggish	25	21.19	37. Over critical of others	2	1.69
8. Day dreaming	22	18.65	38. Unhappy; depressed type	2	1.69
9. Disturbs class routine	21	17.80	39. Whispering	2	1.69
10. Selfish, spoiled	19	16.11	40. Cruelty; or "bully type"	1	.85
11. Talkative; verbose	18	15.26	41. Shyness; timidity	1	.85
12. Cuteness; "smart-alec" type	17	14.41	42. Sissy or tomboy type	1	.85
13. Carelessness	16	13.56	43. Suspicious type	1	.85
14. Generally disorderly in class	10	8.47	44. Temper tantrums	1	.85
15. Nervous; restless; "flighty"	10	8.47	45. Too easily led; suggestible	1	.85
16. Self conscious; egocentric	9	7.63	46. Will not work or play with others	1	.85
17. Cheating	9	7.63	47. Being "just too good"	0	.00
18. Tardiness; not punctual	9	7.63	48. Destructive	0	.00
19. Rudeness; impudence	8	6.79	49. Gambling	0	.00
20. Sullenness	8	6.79	50. Impetuous	0	.00
21. Immature; babyish; "whiney"	7	5.94	51. Physical cowardice	0	.00
22. Impatient	7	5.94	52. Profanity; obscenity	0	.00
23. Pouting; resentful type	7	5.94	53. Stealing	0	.00
24. Overactive; extremely nervous	6	5.09	54. Using tobacco	0	.00
25. Lying	5	4.24			
26. Oversensitiveness	4	3.39			
27. Quarrelsomeness	4	3.39			
28. Sex consciousness	4	3.39			
29. Sickly	4	3.39			
30. Slovenliness	4	3.39			

against whom each trait was checked may be found in Table 1. The problem characteristics most frequently noted were:

1. Lack of interest in work
2. Inattention
3. Will not study
4. Irregular attendance
5. Laziness
6. Quitter type
7. Dull mentally and sluggish
8. Day dreaming
9. Disturbs class routine
10. Selfish; spoiled
11. Talkative; verbose
12. Cuteness; "smart-alec" type
13. Carelessness

It is to be noted that most of the disturbing forms of behavior as noted by the teachers were those which upset class routine, made the disturbing children difficult to teach, and made it difficult to teach the other students.

The mean number of problem traits assigned per student was 4.92 in comparison to the 7.00 obtained by Boynton (2) in working with elementary school children. The mean number of traits assigned by female teachers was 5.03, by the three male teachers a slightly lower figure, 4.83. The mean number of traits assigned by female teachers to boys was 5.3 and to girls 4.5. The mean number of traits assigned by male teachers to boys was 3.6 and to girls 6.6. The three male teachers seem to point out fewer girls as problems but assign to those they do select a greater number of problem characteristics.

Both male and female teachers assigned the same four traits with the greatest frequency to the problem boys: inattention, irregular attendance, lack of interest in work, and laziness. Those characteristics most often associated with the girls were lack of interest in work, selfishness, dull mentally, and sluggish. These results tend to indicate that, in so far as this group of teachers is concerned, boys, more often than girls, are rated as problems for infractions of discipline.

The returns of the second check list were quite different from those of the first. The mean number of traits here assigned to a student was 6.1 as opposed to 4.92 for the first check list. This difference might be accounted for by the fact that the second check list was longer than the first and had a wider range of behavior traits than its predecessor. Furthermore, the second check list contained not only behavior problem characteristics but also a series of desirable traits. Female teachers assigned 6.6 traits per boy and 6.5 per girl. The four male teachers who responded to the second check

TABLE 2

THE FREQUENCY AND PER CENT OF INCIDENCE OF CHECK LIST CHARACTERISTICS ASSIGNED BY TEACHERS IN 210 RATINGS OF 95 OF THEIR PUPILS, ALREADY RATED AS PROBLEMS BY ONE OR MORE OF THEIR PRESENT TEACHERS

Characteristic	Freq.	Per cent	Characteristic	Freq.	Per cent
1. Polite, respectful	60	28.50	36. Cheating	10	4.73
2. Friendly; good mixer; popular	58	27.60	37. Generous; unselfish	9	4.29
3. Inattentive in class; indifferent	57	27.14	38. Adventuresome	8	3.80
4. Dull; sluggish mentally	51	24.25	39. Original; independent thinker	8	3.80
5. Happy; cheerful; good natured	50	23.80	40. Over critical of others	8	3.80
6. Lazy; sleepy; apathetic	46	21.90	41. Unhappy; depressed; moody	8	3.80
7. Irregular in school attendance	45	21.41	42. Pouting; resentful type	8	3.80
8. Talkative; verbose	45	21.41	43. Rude; defiant; impudent	7	3.33
9. Lack of interest in work	43	20.43	44. Self-reliant; independent	7	3.33
10. Tidy; neat	43	20.43	45. Systematic; methodical	7	3.33
11. Disobedient	40	19.10	46. Investigative; desirably curious	6	2.85
12. Cute; "cocky"; "smart alec"	36	17.14	47. Lying; generally untruthful	6	2.85
13. Day dreaming	32	15.23	48. Self controlled; stable	6	2.85
14. Whispering	25	11.90	49. Uses tobacco	6	2.85
15. Tardiness; not punctual	25	11.90	50. Domineering type (but not cruel)	5	2.38
16. Likes jokes; sense of humor	25	11.90	51. Quarrelsome; antagonistic	5	2.38
17. Nervous; restless; flighty	24	11.42	52. Sickly	5	2.38
18. Self-conscious; egocentric	24	11.42	53. Cruel; bully type	4	1.90
19. Dishonest; unreliable	21	10.00	54. Precocious; brilliant	4	1.90
20. Disturbs class; interrupts	21	10.00	55. Slovenly, dirty	4	1.90
21. Honest; truthful	20	9.50	56. Writes notes	4	1.90
22. Selfish, spoiled	19	9.05	57. Destructive	3	1.43
23. Artistic, loves beauty	19	9.05	58. Temper tantrums	3	1.43
24. Impetuous in own actions	17	8.10	59. Goodygoody; "just too good"	3	1.43
25. Dependable; reliable	15	7.14	60. Sissy or tomboy type	3	1.43
26. Energetic (physically)	15	7.14	61. Suspicious type	3	1.43
27. Immature; babyish; "whiney"	15	7.14	62. Sympathetic type	3	1.43
28. Persistent; not a quitter	13	6.19	63. Gambling	2	.95
29. "Quitter"; easily discouraged	13	6.19	64. Leader; takes charge	2	.95
30. Stubborn; "hard headed"	13	6.19	65. Truant	2	.95
31. Sex conscious	12	5.71	66. Will not work or play with others	2	.95
32. Over sensitive about self	11	5.24	67. Physical cowardice	0	.00
33. Ambitious about self	10	4.73	68. Profane; obscene	0	.00
34. Impatient with others	10	4.73	69. Stealing	0	.00
35. Suggestible; too easily led	10	4.73	70. Too easily frightened	0	.00

list assigned 3.2 problem characteristics per boy and 5.5 per girl. A list of the traits in the second check list, the frequency with which each appeared, and the percentage of children against whom each trait was checked may be found in Table 2. The 10 traits most frequently noted in this second inventory were:

1. Polite and respectful
2. Friendly; good mixer; popular
3. Inattention in class; indifferent
4. Dull; sluggish mentally
5. Happy; cheerful; good natured
6. Lazy; sleepy; apathetic
7. Irregular school attendance
8. Talkative; verbose
9. Lack of interest in work
10. Tidy; neat

Without doubt four of the above list of traits, namely 1, 2, 5, and 10, are desirable characteristics. It is indeed notable that when the entire faculty had the opportunity to rate those of their pupils who had been designated as problems by one or more of their teachers, the two most frequently noted traits were decidedly favorable to the students. Among the seven traits most frequently noted by female teachers for both boys and girls five were identical for each group. These were as follows: (*a*) friendly and good mixer, (*b*) happy; cheerful; good natured, (*c*) polite and respectful, (*d*) inattentive in classrooms, and (*e*) irregular attendance in class. There was but little difference between the problem characteristics most frequently assigned by the four men teachers to both the boys and the girls. These were: (*a*) polite and respectful, (*b*) talkative and verbose, (*c*) lazy, (*d*) inattentive in class, (*e*) happy; cheerful; good natured, and (*f*) friendly and good mixer.

Thus, it is seen that, to the extent that the secondary school herein considered is typical, the problem child is rarely a problem to all of his teachers but tends to present difficulty to but one instructor. Furthermore, the fact that a student is regarded as a behavior problem by one teacher does not preclude the possibility that he may be considered a well-adjusted individual by all of his other teachers. We also note that the reasons for which boys are designated as problems in the secondary school do not differ greatly from those for which girls are classified as problems, regardless of the sex of the teacher. It is regrettable that there were so few male teachers in this study, a factor which prevents a reliable comparison of the judgments of the male and female teachers.

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MEASURES OF TENDENCY-TO-CONTINUE: I. BEHAVIOR OF FEEBLEMINDED AND NORMAL SUBJECTS FOLLOWING THE INTERRUPTION OF ACTIVITIES*

Department of Psychology, University of North Carolina

DOROTHY RETHLINGSHAFER[1]

A. INTRODUCTION

The purpose of this study is to determine whether any differences exist between feebleminded and normal subjects of the same mental ages, when they are compared in their behavior following the interruption of activities. The technique is based upon the method developed by Ovsiankina (2) who extended the basic investigation of Zeigarnik (4) by analyzing in detail the problems inherent in the resumption of interrupted tasks.

Köpke carried out similar experiments with feebleminded and normal subjects; though the mental ages of his children were not reported, the chronological ages of his mentally deficient were 8 to 9 years and for the normals 7 to 8 years. Kopke's unpublished study has been reported by Lewin in his discussion of *A Dynamic Theory of the Feebleminded* (1, pp. 194-238).[2] Köpke found that his feebleminded group were quite high in resumption; when no substitute followed the interrupted activity, resumption was 100 per cent as contrasted to 79 per cent for the normal group. And even when a substitute followed the interrupted work, the resumption of the feebleminded remained at 94 per cent while the normals' records sank to 33 per cent. "Köpke then gradually increased the similarity of the main and substitute activities until they were practically identical: for the task *'paint an animal'* was substituted the task *'paint the same animal again on another sheet of paper'*; for *'build a bridge*

*Received in the Editorial Office on April 27, 1940.

[1]This research was done as partial fulfillment of the doctoral degree at the University of North Carolina The writer is indebted to Drs. J. F. Dashiell and R. J. Wherry. Through the coperation of Dr James Lewald, the feebleminded subjects were obtained

[2]Dr. Lewin also very kindly furnished the experimenter a copy of Kopke's original work

out of stones' was substituted *'build the same bridge out of stones'* " (1, p. 204). Nevertheless resumption under these conditions remained at 86 to 100 per cent for the feebleminded.[3]

However, when Kopke after interruption placed barriers between the initial undertaking and his feebleminded subjects, the activity was very likely to remain uncompleted. Lewin, interpreting this result, states, "In higher degree than the normal the feebleminded is *either in the one or in the other situation*. Separate situations are in much higher degree opposed closed wholes, and the feebleminded acts according to the field forces of these closed situations" (1, p. 216).

From the results of Köpke with the defective children Lewin describes the personality of the feebleminded:

> This abnormal frequency of resumption is a consequence of the fact that a tension system, once it is built up, stays unchanged without being diffusely discharged. The experimental result agrees with the observations of daily life that feebleminded children are often extremely stubborn and that it is relatively difficult for such a child to change his goal after he has set himself toward it. This well-known stubbornness is a result of the rigidity of his psychological system (1, p. 188).

Lewin's description of the feebleminded as being peculiarly rigid in their fixation on goals, is in contrast to a statement made by Pintner: "In summing up these studies of the mental characteristics of the feebleminded, one gets the impression that, taken as a group, they are very much like normal children of the same mental age" (3, p. 828).

Though the latter statement is based upon a consideration of the "mental characteristics" and those of Lewin are directed at describing the "personality" of the feebleminded, yet a consideration of the views of both men suggests the question: Are the feebleminded sufficiently different from the normals so that they could not be described as being "like normal children of the same mental ages?"

The problem of this study was to determine whether feebleminded and normal children of the same mental ages differed in their behavior following the interruption of activities in which they were engaged.

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[3]No normal subjects were used in these or remaining experiments of Köpke.

B. Subjects

Köpke's criteria of normality and of feeblemindedness was apparently only school placement. The choice of the two groups in this study was on the basis of intelligence quotients from the Stanford Revision (first) of the Binet-Simon tests. Using Terman's classification, the experimenter classified children as normal (average) whose intelligence quotients were between 90 and 110. The feebleminded group ranged in *IQ* from 42 to 70 but all but one were above 47. Hence this study deals primarily with that group of mentally defectives called morons. The two groups were further selected so that they were equated on their mental ages which ranged from 6 to 9-11.

A further criterion of feeblemindedness was met to the degree that the defective children came from an institution where for varying reasons they had been placed when they had not been able to fit into an outside environment. Twenty-nine white feebleminded children in the District Training School, Laurel, Maryland, a federal institution for the mentally defective, were used, and an equal number of normal children were obtained from the Chapel Hill Graded School, Chapel Hill, North Carolina.

C. Procedure

1. *Experimental Room*

It was decided as far as possible to clear the field. Only necessary furniture was left in the experimental room, two tables and four chairs. The walls were plain. All the materials necessary in the activities (as puzzles, blocks, etc.) were out of sight until needed. A special experimental table, constructed to make this possible, was also large enough so that, if desired, the presentation of a substitute activity could be made without removing or crowding the interrupted activity.

2. *Preliminary Period with Each Subject*

While the subjects were placed in a frankly experimental set-up, the experimenter, before and during the various activities, attempted to create in the subjects a feeling of freedom in the experimental room, varying her methods according to the chronological ages of the subjects. With a few exceptions the experimenter had already given

intelligence tests to both the normal and feebleminded subjects and had at that time also established rapport.

3. *General Procedure*

Eleven short experiments were performed with the subjects individually in two experimental periods. In order to clarify the general technique used in these resumption experiments, the following description is given, and then a more detailed presentation of the procedure in each experiment will follow.

The choice of activities was made with a view of direct comparison with Kopke's results, but it was impossible to duplicate his activities exactly, either because the material could not be obtained in this country, or his description was incomplete. Moreover as we were comparing feebleminded and normals of known mental ages, it was necessary to select activities which could be performed successfully (finished) by the subjects of these mental ages, and this was determined by preliminary trials. However, tasks of the same general type as Köpke's tasks were used, the original activities to be interrupted being puzzles, block patterns, modeling different animal figures, tracing patterns on paper, and cutting designs from paper. Köpke had used puzzles, modeling animals, copying animals, cutting out figures from paper, and building from stones.

All of our activities had definite goals, stated in the directions given to the subjects. So many pieces were to be fitted together in a puzzle, a certain figure to be cut from paper, an animal to be made from clay, and the like.

Following the choice of activities, the next step was the determination of when and how to interrupt the subjects. If a subject was working on a puzzle, the experimenter had to stop him at a predetermined time, i.e., at the beginning or in the middle of the puzzle, or near the end. In all of our 11 experiments the interruption was at a standard place for all subjects, approximately when one-half of the original activity was completed. The place and method of interruption used in each experiment are described in Table 1.

The attempt to interfere with the subject may not succeed. If the subject continued to work, there arose the question as to how much "pressure" should be placed upon him. In our series of experiments, the experimenter repeated without change of tone, every 15 seconds the words used in first attempting the interruption. If

TABLE 1

Problems	Experiments	Materials for first activity	Place of interruption	Method of interruption	Kind of substitute	Barrier
I Substitute vs no substitute for the original interrupted activity	1	14 piece puzzle	7th piece	Experimenter asks subject questions	none	none
	2	17 piece puzzle	7th piece	Presentation of substitute	17 piece puzzle	none
	3	Making a plasticine duck	One-half completed	"	33 colored wooden beads to string	none
II Effect on resumption of similar substitutes	4	Making a plasticine cat	"	"	Making a smaller plasticine cat	none
	5	Tracing an animal figure	"	"	Tracing the same figure	none
	6	Cutting out an airplane pattern from green paper	"	"	Cutting the same pattern from red paper	none
III Effect on resumption of barriers	7	17 piece puzzle	7th piece	"	17 piece puzzle	Space barrier
	8	Same puzzle as in experiment 2	7th piece	"	Same substitute as in experiment 2	Cover placed over puzzle
	9	Making plasticine pig	One-half completed	"	Coloring picture of pig	Space barrier
IV Destruction of original activity	10	11 blocks in pattern	6th piece	Experimenter destroys pattern	11 blocks in different pattern	?
V Effect on resumption of other materials on table	11	16 large blocks	10th piece	Experimenter asks subject to help her	none	none

a new puzzle had been offered to the subject, the experimenter would repeat the words, "*Now I want you to make an auto out of these pieces,*" indicating the proffered puzzle, and would continue to repeat these same words at a uniform time interval. If the subject did not stop working on the original activity in spite of the presence of the new activity, and the repetition of the directions, this "pressure" was continued until either the subject was finally arrested, or had finished the original activity. In most cases the subjects yielded to this "pressure," but out of 638 records, 31 were obtained of complete-refusal-to-be-interrupted and 149 records of part-refusal-to-be-interrupted.

Whatever the method of taking the subject away from the first activity or whatever he does during the period of interruption, the next and important step is to give him an opportunity to return to the original activity. It would be best if the observations at this time were from a one-way screen. This was not possible in our experiments, but the experimenter as far as possible was in the background at this time, writing industriously in her notebook while she actually observed the subject.

Time records were kept with a standard stop watch of the seconds elapsing before interruption; of the time any subject worked if he refused to be interrupted; and of the length of the interruption period. When the interruption was over and the subject was free to return to the original activity, the experimenter also recorded the time that elapsed before resumption took place. Sometimes, of course, there was no delay but rather immediate resumption. Again there might be no return to the original activity; in that case there was a standard five-minute wait before a new experiment was started. Finally if the subject returned to the first activity, the last record was the time that he worked until he either had finished the task or had quit.

In the above it is stated that resumption may be delayed and that if the subject did not resume within five minutes after the opportunity for resumption was given him, the experiment was terminated. The choice of five minutes was based upon the fact that resumption is usually immediately after, or very soon thereafter, the finishing of the substitute activity.[4]

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[4]Only five of the total 201 delayed resumptions were after a 4-minute wait.

4. *Procedure in the 11 Experiments*

The procedure in each experiment[5] is summarized in Table 1 where are likewise stated the five problems at which the 11 experiments were directed. Experiments 1, 2, and 3 were run to answer the first problem: Will the resumption of the feebleminded be more affected than that of the normals by the introduction of a substitute for the initial blocked activity? Then in Experiments 4, 5, and 6 the second activity was made more similar to the task for which it was to act as a substitute. It is difficult to determine the degree of similarity of two activities. There is, however, objective similarity: cutting an airplane pattern from one piece of paper has objective similarity to cutting the same pattern from another piece of paper.

The opportunity to resume the interrupted activity may be blocked by the introduction of barriers of various types. In Experiments 7 and 9 space barriers were created by moving the subject away from the main experimental table and placing him before a substitute activity on a smaller table so that he could not see the first interrupted task. In Experiment 8 the barrier was raised by the experimenter covering the interrupted puzzle. In Experiment 10 a block pattern was interrupted by the experimenter destroying the half-completed work, and in Experiment 11 the question of whether boredom may have led the subjects back to the original activity was attacked by placing upon the table with the interrupted work various other materials.

D. Results

1. *Types of Behavior Following Interruption*

An examination of the records of behavior that were obtained following interruption of 11 different activities revealed various types of behavior fairly easily differentiated from each other. As the strongest evidence of tendency-to-continue the experimenter classified together those records where the subject refused completely to be interrupted in spite of standard pressure placed upon him. Frequently the subject objected verbally to the interruption and also clung to the original activity in spite of the presentation of the

[5]A detailed description of the materials used, and of the standard methods of presentation and of interruption of each experiment is on file at the University of North Carolina library.

new material and the direction of the experimenter, *"Now do this one."*

No attempt is made to use the comments of the subjects at the moment of the interruption as evidence of tendency-to-continue, but some are now quoted merely to illustrate the situations where there was complete-refusal-to-be-interrupted. Often the subjects said at the presentation of the new task, *"Just a minute,"* and continued working on the old one, or *"I want to finish my ———,"* naming whatever object was being constructed. If interrupted when cutting out a pattern, *"Just as soon as I finish cutting this one out,"* or *"Wait 'til I finish this one."*

Many subjects objected to the interruption but finally yielded to the experimenter's pressure. These subjects left an incompleted activity, though a task often brought very close to completion. When the interruption period was over, they had an opportunity to resume, and some took immediate advantage of it. When they had "bucked" at an interruption but finally yielded to the experimenter, then immediately returned to the incompleted work, they are placed in this second type of behavior: a part-refusal-to-be-interrupted and immediate resumption.

Some records showed a part-refusal-to-be-interrupted on the original activity, no immediate resumption, but a return after a period of delay. A subject objects to being interrupted on a puzzle, keeps on working but finally quits before completing the puzzle, turns to the substitute, finishes it, and though he now has an opportunity to resume the first interrupted puzzle, he does not do so immediately. However after a period of delay, he resumes and finishes the interrupted puzzle. Such subjects whose records showed a part-refusal-to-be-interrupted and delayed resumption were also further classified into those who delayed one, two, three, four, and five minutes.

Some subjects showed no objection to being interrupted. Among such individuals were those who immediately resumed. They were easily stopped, but as soon as they had an opportunity, they started again upon the original activity. Such records indicated that though there had been no refusal to be interrupted, a tendency-to-continue was shown in the behavior, described as immediate resumption.

Other subjects who also had not objected to the interruption delayed their return to the original activity. They were classified under different intervals of delay as outlined above, and this type

of behavior was called no-refusal-to-be-interrupted and delayed resumption. These subjects had not objected even in part to being interrupted and they likewise had delayed their return to the first task.

Two records showed a refusal in part to be interrupted and then later only a tendency to resume. We defined tendency to resume as starting, then stopping the original activity, resuming it again, and finally stopping it without completing it.[6]

Some subjects did not resume the original activity and those records were, of course, listed as non-resumption. Among these we find a small number indicating that when the interruption was made, the subjects had attempted to continue the original activity, but once stopped they had never returned. They had shown a part-refusal-to-be-interrupted but never any resumption.

The behavior of a few subjects following interruption showed only a tendency to resume, the same definition being applied as in the class above, going back to the original activity, stopping, starting, but never completing.

And last, as the measure of no tendency-to-continue an activity, we place no resumption.

If a scale were made of "persistency," indicating at one end a "strong" tendency-to-continue, the following forms of behavior after an interruption could be listed:

I. Complete-refusal-to-be-interrupted.
II. Part-refusal-to-be-interrupted and immediate resumption.
III. Part-refusal-to-be-interrupted and delayed resumption of one minute,
IV. of two minutes,
V of three minutes,
VI of four minutes,
VII of five minutes
VIII No-refusal-to-be-interrupted and immediate resumption
IX. No-refusal-to-be-interrupted and delayed resumption of one minute,

[6]A subject may touch, or say words concerning, or direct his attention in some other manner, to the original unfinished activity, yet not actually resume This form of behavior has been called by some experimenters a "tendency to resume," but was not so counted as resumption in these series of experiments

X. of two minutes,
XI. of three minutes,
XII. of four minutes,
XIII. of five minutes.
XIV. Part-refusal-to-be-interrupted and tendency to resume.
XV. Part-refusal-to-be-interrupted and no resumption.
XVI. No-refusal-to-be-interrupted and tendency to resume.
XVII. No-refusal-to-be-interrupted and no resumption

2. *Distribution in the Above Classification of 638 Records of Behavior Following the Interruption*

In the judgment[7] of the experimenter the order of the above classification of behavior following interruption is from "strong" tendency-to-continue to "weak" tendency-to-continue an activity. These classes are used as points upon which are plotted in Figure 1

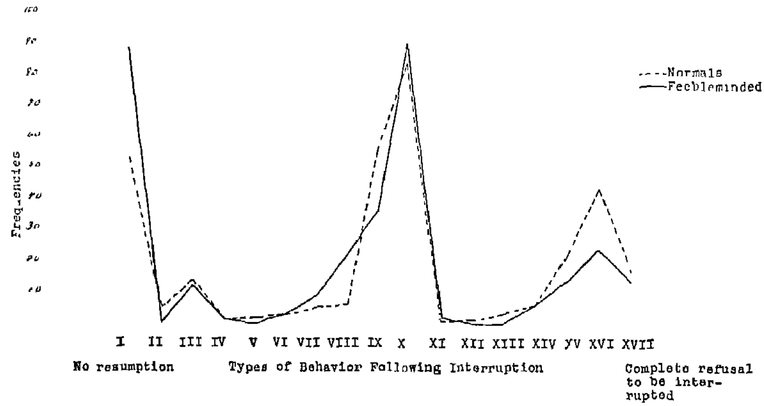

FIGURE 1
DISTRIBUTION OF THE 17 TYPES OF BEHAVIOR FOLLOWING INTERRUPTION

the 638 records of behavior following interruption of 29 feebleminded and 29 normal subjects. Examining Figure 1 we see that the feebleminded and normal subjects exhibit the same types of

[7]The order of these 17 different types of behavior was based upon (*a*) their logical relationships and (*b*) an examination of the records in doubtful cases (as Types XIV and XV) to determine whether individuals manifesting these types of responses would be high or low in the other types of behavior.

behavior along the scale from complete-refusal-to-be-interrupted to "weak" tendency-to-continue as indicated by non-resumption. However the feebleminded have more non-resumptions and also fewer records toward the end of the scale where "strong" persistency was recorded. In contrast to the results of Köpke the feebleminded of our group have less tendency-to-continue an activity than normal subjects of the same mental ages.

3. *Representing the Data on a Normal Scale*

By making the assumption that the law behind the data is a normal distribution, a qualitative series of observations, as were the above records of behavior shown in Figure 1, can be converted into a quantitative continuum.[8] The midpoints of each class were marked in sigma units from the mean taken as zero. This gave a sigma range of 3.2 between the weakest measure (non-resumption) and the strongest evidence of tendency-to-continue (complete-refusal-to-be-interrupted). As is seen in Figure 1 and also as was found in making the scale, the categories of behavior used to indicate different degrees of persistency do not provide fine enough differentiation of the records which are lumped together at either end of the scale. Moreover, non-resumption does not extend as far from zero as complete-refusal-to-be-interrupted, indicating that the scoring methods were most in need of extension at this end of the scale, either by different analysis of the behavior shown, or by the inclusion of other interrupted activities. Probably also by means of different grades of barriers more differentiation of response might be obtained. We also found that the sigma values, when kept to a single decimal place, did not distinguish between certain of the classes of behavior which we had found by the qualitative differentiation. The classes of behavior which received the same scale values were grouped together.

Table 2 shows these combinations of classes, and the score value of the median of each class on the scale; the frequency in each of the combined classes; and the percentage represented in each class

[8]The total frequencies in each class were expressed in percentages; the cumulative percentages to the median of each class were obtained; then by using the percentage above or below 50 per cent for each of the midpoints of the sub-groups, the distances out to these medians, from a mean point taken as zero, were read in sigma units from a table giving areas and corresponding *z* scores for a normal curve.

TABLE 2
FREQUENCIES OF TYPES OF BEHAVIOR FOLLOWING INTERRUPTION, WITH CERTAIN TYPES COMBINED ACCORDING TO SIMILARITY OF THEIR SIGMA UNITS ON A SCALE OF TENDENCY-TO-CONTINUE

Types of behavior following interruption	Score value on scale	Frequency of F. M.	Per cent of F. M.	Frequency of normals	Per cent of normals	Differences between percentages	Difference in favor of	σ Diff.	C.R.
A No resumption	—1.2	88	27.6	53	16.6	—11.0	F. M.	3.26	3.37
B. Tendency to resume	—.8	0	0	5	1.6	1.6	Normals	.70	2.29
C. Part-refusal-to-be-interrupted and no resumption	—.7	12	3.8	13	4.1	.3	Normals	1.54	.19
D. 1. Part-refusal and tendency to resume.			.9	6	1.9	1.0	Normals	.94	1.03
2. Delayed resumption (3 to 5 min.)	—.6	3							
E. Delayed resumption (1 to 3 min.)	—.5	31	9.7	11	3.5	—6.2	F. M.	1.95	3.18
F. Delayed resumption (0 to 1 min.)	—.2	36	11.3	55	17.2	5.9	Normals	2.76	2.14
G. Immediate resumption	.3	89	27.9	83	26.0	—1.9	F. M.	3.51	.54
H Part-refusal-to-be-interrupted and delayed resumption (2 to 5 min.)	7	2	6	5	1.6	1.0	Normals	83	1.17

TABLE 2 (*continued*)

Types of behavior following interruption	Score value on scale	Frequency of F. M.	Per cent of F. M.	Frequency of normals	Per cent of normals	Differences between percentages	Difference in favor of	σ Diff	C.R.
I. Part-refusal-to-be-interrupted and delayed resumption (1 to 2 min.)	.8	6	1.9	6	1.9	0			
J. Part-refusal-to-be-interrupted and delayed resumption (0 to 1 min.)	.9	14	4.4	22	6.9	2.5	Normals	1.83	1.37
K. Part-refusal-to-be-interrupted and immediate resumption	1.3	24	7.5	43	13.5	6.0	Normals	2.42	2.48
L. Complete-refusal-to-be-interrupted	2.0	14	4.4	17	5.3	.9	Normals	1.70	.53

of behavior of the total records, 319 records for 29 feebleminded and 319 records for 29 normal subjects. Likewise the differences between the percentage frequencies of the feebleminded and normals at the various points on the scale were obtained. In Table 2 under the seventh column headed "Difference between percentages," we see that there are three points where the feebleminded have a greater percentage frequency (*A*, *E*, and *G*). At all the other points the normals are superior. In the last column the critical ratios of the differences are given.

However, mere examination of some difference and of its critical ratio is not sufficient unless it is also noted at what point on the scale the difference exists, i.e., at the end of the scale where "weak" persistency is measured or where the behavior indicates "stronger" tendency-to-continue. As Figure 1 had indicated, the feebleminded differ from the normals at either end of the scale, having more non-resumption records and on the other hand showing less frequently those forms of behavior that indicate "stronger" persistency. Table 2 bears out this same graphic portrayal, for examining the differences in percentages and the critical ratios we see that the feeble-minded have significantly more non-resumptions than normals (Critical ratio of 3.37 at Point *A*). From then on up the scale, though increasing tendency-to-continue is being measured, the feebleminded have only one other significant greater frequency; at delayed resumption (1 to 3 minutes) the difference is in favor of the feebleminded with a critical ratio of 3.18 (Point *E*). At the upper point of the scale the normals increase in their superiority in the number of records. The critical ratio of 2.48 at the *K* point, called part-refusal-to-be-interrupted and immediate resumption, indicates 99 chances out of 100 that the normals are superior in tendency-to-continue at this upper point on the scale. Our general analysis of the results, when use is made of scale values would not indicate that the feebleminded have more tendency-to-continue, as measured by behavior following interruption, when they are compared to normal subjects of the same mental ages.

E. Summary

The purpose of this study was to compare feebleminded with normal subjects of the same mental ages in their behavior following the interruption of activities in which they were engaged. Köpke

had found feebleminded children resuming more frequently than normal subjects but the mental ages were unreported. Lewin, using Köpke's study in his interpretation of the personality of the feebleminded child, had stated that such children had a greater goal fixation than normal children.

On the basis of known mental ages (6 to 9-11) 29 feebleminded and 29 normal subjects were interrupted in 11 different activities and records of their behavior following the interruptions were made. The 638 records obtained from the 11 different experiments were classified into 17 different types of behavior, ranging from what was called "strong" to "weak" tendency-to-continue.

These 17 different types of behavior following interruption were converted into a normal scale ranging from high to low scores on tendency-to-continue. When the scale scores were obtained, these 17 different types of behavior were reduced to 12 differentiating classes by grouping certain classes that had the same scale score when the sigma units were kept to one decimal place. At the upper points on the scale delayed resumptions of two to five minutes were put together. At the lower end of the scale the five types of no-refusal-to-be-interrupted and delayed resumptions were reduced to three types.

An analysis of the data comparing percentage of feebleminded against percentage of normals at the various points on the scale showed the two groups exhibiting the same types of behavior, but the feebleminded were distributed at the lower end of the scale with two significant differences in their favor; at non-resumption the critical ratio was 3.37 and at delayed resumption of one to three minutes the critical ratio was 3.18. The normals were more numerous at the upper points on the scale though none of the differences in favor of the normals had a critical ratio of over three. At part-refusal-to-be-interrupted and immediate resumption the critical ratio of 2.48 indicated a difference at this upper point of the scale of tendency-to-continue in favor of the normals.

The feebleminded of the mental ages used do not have any greater "goal fixation" than normal subjects of the same mental ages. The normal subjects not only resumed more frequently but were at the positive end of the scale of tendency-to-continue while the feebleminded were distributed toward the lower end.

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Department of Psychology
University of North Carolina
Chapel Hill, North Carolina

The Journal of Genetic Psychology, 1941, 59, 125-138.

MEASURES OF TENDENCY-TO-CONTINUE: II. COMPARISON OF FEEBLEMINDED AND NORMAL SUBJECTS WHEN INTERRUPTED UNDER DIFFERENT CONDITIONS*

Department of Psychology, University of North Carolina

DOROTHY RETHLINGSHAFER

A. INTRODUCTION

In a recent publication (4) a general comparison was made between the behavior of feebleminded and normal subjects of the same mental ages when they were interrupted in 11 different activities. The 638 records of behavior from all subjects were classified into categories ranging from such behavior as complete refusal to be interrupted to no resumption of the original activity. These qualitative categories were converted into a quantitative scale of tendency-to-continue and given scale values in sigma units.[1] Comparison of the feebleminded and the normal subjects on this scale would indicate that the normal children showed more tendency-to-continue than the less intelligent. This was contradictory to an unpublished study by Kopke whose work was reported by Lewin (2) in support of his theory of the personality of the feebleminded child who was described as having greater goal fixation than a normal child.

Kopke had likewise compared his feebleminded and normal subjects under various specific conditions. It was therefore felt that the results obtained from the same subjects used in the preceding paper should be analyzed to answer the following six specific questions similar to the problems attacked by Kopke.

I. As it has been found that resumptions of an interrupted activity are decreased when a substitute activity follows the interruption (3), the feebleminded and normal groups were compared under this condition.

II. Since greater "satisfaction" is supposedly gained by a substitute similar to the original interrupted activity, the subjects do

*Received in the Editorial Office on April 27, 1940.

[1]See page 119 of (4) for a description of this scale.

not return so frequently to the first task (3). The two groups were compared when the second activity was increased in "objective" similarity to the original interrupted activity.

III. If a physical barrier of some nature, as hiding the interrupted activity, is set up so that the subject cannot easily resume, a third type of condition is introduced and records of resumption behavior were made of normal and feebleminded subjects with different barriers.

IV. When the interruption of the original activity is by the destruction of the work that has been completed up to the destruction, as by breaking up a partially formed pattern made with blocks, a fourth condition is tested for its influence on resumption.

V. As the field was cleared between each experiment, it seemed possible that resumption might have taken place because of the lack of anything else to do. In order to test this assumption the experimenter placed on the table with an interrupted activity, other materials as blocks, puzzle, scissors, paper, and clay.

VI. Interruptions were made in a series of five identical patterns made from blocks, and also in a series of five different patterns. It was thought possible that identical block patterns would "demand more completion" than a series of different patterns, i.e., resumption would be more immediate and more frequent. The effect of these situations on the two groups of subjects was also of interest.

B. Procedure

The description of the procedure used in 11 of the different experiments set up to answer the preceding problems is given in the first paper and is not here repeated. Experiments 12 and 13, designed to answer the sixth problem, had a separate section devoted to its procedure and results.

C. Subjects

Thirty feebleminded subjects of intelligence quotients between 42 and 70 were chosen from an institution for the mentally defective, and 30 normal children with *IQ*'s within 90 to 110 were obtained from the Chapel Hill Graded School. They ranged in mental ages from 6 to 9-11 and were approximately equated in the number represented at each year level.

D. Results

Our previous analysis (4) of the results indicated that the feebleminded and normal subjects of the same mental ages exhibit the same types of behavior following interruption. Köpke's records were principally in terms of resumption or non-resumption of the original activity. Other forms of behavior that we have used as evidence of tendency-to-continue include complete-refusal-to-be-interrupted, part-refusal-to-be-interrupted, immediate resumption, delayed resumption of varying time intervals, tendency to resume, as well as various combinations of the above. It was on the basis of this finer differentiation of behavior following interruption that a scale[2] was constructed ranging from weak evidence of tendency-to-continue, as non-resumption, to our strongest evidence of persistency, the complete-refusal-to-be-interrupted records. By means of the scale values each subject was scored in the first 11 experiments, and means and standard deviations for the feebleminded and normal subjects were obtained. Differences between these means and critical ratios of the differences are given in Table 1 and will be referred to as each problem is considered.

1. *Problem I*

The question was raised whether feebleminded and normal subjects could be differentiated in their behavior when a substitute was given (Experiment 1) and when no substitute was used (Experiments 2 and 3). Examining Table 1 we find no significant difference in means between the two groups in any of the first three experiments. Comparing the averaged means of the feebleminded against the normals when a substitute was given, we have .160 for the feebleminded and .242 for the normals. If we subtract these from their mean performance when no substitute was given, we see for the inferior intelligent a decrease of .130 and for the normal children a decrease of .144 down the scale of tendency-to-continue. A substitute should tend to decrease the scores on the scale (3) and we find the feebleminded and normals decreasing approximately equally.

Köpke's results are expressed in percentage of resumption or non-resumption. As he does not make the differentiation in behavior

[2]Only 29 subjects from each group were used in making the scale (4).

TABLE 1

MEAN PERFORMANCE IN SCALE VALUES AND CRITICAL RATIOS OF THE DIFFERENCES BETWEEN THE MEANS

Experiments		Subjects	Mean	*S.D.*	Difference between means	σ of the difference	*C.R*
No substitute used	1	F.M.	.290	.94	096	234	.41
		Normals	.386	.84			
Substitutes used	2	F.M.	.228	66	048	.198	.24
		Normals	.276	82			
	3	F M	.093	.81	.114	230	50
		Normals	.207	.93			
Average of Experiments 2 and 3		F M.	.160				
		Normals	.242				
Average of Experiments 1, 2, and 3		F M.	203				
		Normals	290				
Similar substitutes used	4	F.M.	.255	1.04	.117	.282	.41
		Normals	.372	1 10			
	5	F.M.	—.100	.86	.769	.226	3.40
		Normals	.669	.86			
	6	F.M.	.090	.95	700	221	3 17
		Normals	610	71			
Average of Experiments 4, 5, and 6		F M.	.022				
		Normals	.550				

TABLE 1 (*continued*)

Experiments		Subjects	Mean	S D	Difference between means	σ of the difference	C.R
Barriers present	7	F.M	—.450	.93	.428	.231	1.85
		Normals	—.031	.81			
	8	F.M.	—.990	.44	.269	.160	1.68
		Normals	—.721	.74			
	9	F.M.	—.572	.64	.162	.179	.91
		Normals	—.410	.71			
Interruption by destruction	10	F.M	—.324	.59	.155	.130	1.19
		Normals	—.169	.49			
Average of Experiments 7, 8, 9, and 10		F.M.	—.586				
		Normals	—.333				
Other materials on table	11	F.M	.507	.63	—.107	.159	.67
		Normals	.400	.58			
Totals		F.M.	—1.166	4.79	2.756	1.33	2.06
		Normals	1.590	5.35			

Positive means are at the "strong" end of the scale of tendency-to-continue, negative scores at the "weak" end of the scale.

TABLE 2

FREQUENCY OF RESUMPTION WHEN A SUBSTITUTE IS USED, WHEN IT IS NOT USED, AND WHEN IT IS INCREASED IN SIMILARITY TO THE ORIGINAL INTERRUPTED ACTIVITY

(Results in this study are compared to the results of Köpke)

	Results in this study			Results in Köpke's study		
		Per cent of resumption			Per cent of resumption	
	No.	Without substitute	With substitute	No.	Without substitute	With substitute
		Experiment 1	Experiment 2			
F.M	30	92	90	21	100	94
Normals	30	93	90	34	79	33
			Experiment 3			
F.M.	30		83	10	100	90
Normals	30		75	15	80	33
		Totals	Totals		Totals	Totals
F.M.	60	92	87	31	100	92
Normals	60	93	83	49	80	33
Substitute Increased in Similarity to the Original Interrupted Activity						
		Non-similar substitutes	Similar substitutes		Non-similar substitutes	Similar substitutes
		Experiment 2	Experiment 4			
F.M.	30	90	70	13		93
Normals	30	90	60			
		Experiment 3	Experiment 5			
F.M.	30	83	69	7		86
Normals	30	75	92			
			Experiment 6			
F M.	30		64	13		100
Normals	30		96			
		Experiments 2 and 3	Experiments 4, 5, and 6			Totals
F.M.		87	68			93
Normals		83	83			

following interruption which was made in the construction of our scale, our direct comparisons with his results in Table 2 are likewise in percentage frequencies of resumption. He had found that the normals decreased greatly in their resumption of interrupted activities when a substitute was given them, going down to 33 per cent resumption while the feebleminded on the other hand had decreased very slightly in the number of their returns to the interrupted activity. In one of our experiments the normals also decreased slightly more than the feebleminded in resumptions, when a substitute was offered them, but the two groups do not show the marked difference that Köpke found. Other results from this study likewise contradict the smaller resumption of the normals in this one experiment.

Our conclusion, therefore, in regard to Problem I is that as far as the effect of a substitute upon resumption was investigated in this study, we find that the two groups compared are not significantly different in their behavior following interruption.

2. *Problem II*

The second problem also grew out of a general finding that with normal adults and children an increase in the similarity of the original and substitute activities decreases resumption (3). Our Experiments 4, 5, and 6 were therefore designed to test whether there was a difference between feebleminded and normal children when the substitute was increased in objective similarity to the original interrupted activity.

Kopke had reported, on the basis of a limited number of feebleminded subjects and with no normal subjects as controls, that a greater similarity between the substitute and the original activity had decreased the resumption of his subjects; he had concluded that the feebleminded are strongly fixed on a goal, i.e., even in situations where resumption had been found to be decreased, it remained high for his feebleminded subjects (86 to 100 per cent).

However, examining the means for our Experiments 4, 5, and 6 in Table 1, we see that the normals go up the scale of tendency-to-continue while the feebleminded show contradictory behavior, going down in Experiments 5 and 6 though increasing slightly in 4. Also in our experiments where the feebleminded show a decreasing tendency-to-continue, they are significantly lower than the normal children of the same mental ages with critical ratios of over three.

Likewise a comparison of our results with Kopke's in Table 2 brings out the fact that the increase in similarity of the substitutes to the original activities does not decrease the resumption of the normals. On the other hand our feebleminded sink from 87 per cent resumption in Experiments 2 and 3 to 68 in Experiments 4, 5, and 6. Our normal group rather resemble Köpke's results with the feebleminded.

Since a "tension" system is supposedly discharged more easily when the substitute is similar to the original interrupted activity, and resumptions, therefore, usually less in such situations, Köpke's results, with high resumption of his feebleminded had apparently indicated peculiarly rigid fixation on a goal, and in such language Lewin had described the personality of the feebleminded. Our results do not support this conclusion. In fact we find that the normal child as contrasted to the feebleminded individual of the same mental age is more peculiarly fixed on a goal. However, the experimenter would not say that such is the characteristic of the normal children of the mental ages used. The reasons why the normal children did not decrease in resumptions under the conditions in our Experiments 5 and 6 which generally produce decreased resumptions is not known.

If greater similarity between the substitute and the original interrupted activity generally brings a decreased number of resumptions, it would be expected likewise that the number of the immediate resumptions would be decreased. Kopke stated that though resumptions for his feebleminded remained high, more resumptions had been delayed. We find on the contrary that the number of immediate resumptions increase for both groups of subjects. Both our feebleminded and normal subjects resumed more quickly in experiments with similar substitutes than in the non-similar substitute experiments.

The conclusions in regard to Problem II are, therefore, as follows: (*a*) In spite of increased similarity between the original and the substitute activities, the normal subjects as a group are still superior to the feebleminded in their tendency-to-continue the interrupted activities.

(*b*) The number of immediate resumptions increase for both groups of subjects though the increase is greater for the normals than for the feebleminded.

3. *Problems II and IV: Measurement of Barrier Strength*

In Experiments 7, 8, 9, and also in 10, physical barriers were set up by the experimenter in order to see if resumption would be affected. In Experiment 7 the subjects were directed to fit together a puzzle on the main experimental table; then this original activity was interrupted by the experimenter asking the subject to fit together the substitute puzzle on another table, thus creating a space barrier. This same type of barrier was used in Experiment 9 where the interrupted plasticine figure was left while the subject was directed to work on the substitute activity, a drawing, placed on the other table. In Experiment 8 the barrier was made by covering up an interrupted puzzle, and in 10 the experimenter interrupted the laying of a block pattern by pushing the blocks off of the half-completed work. This destroyed the incompleted activity so that nothing remained to be resumed. Whether this last method of interruption should be described as creating a barrier or a new situation is a matter of opinion. However the results in Table 1 indicate that the subjects' behavior in Experiment 10 was similar to their behavior in the barrier situations.

In Table 1 we see the mean scores of these experiments are toward the minus end of the scale where "weak" persistency was measured. This is true for both groups and for all of the four experiments in which the barrier to resumption was present. Covering the interrupted puzzle was the strongest barrier, as indicated by mean scores of —.990 for the feebleminded and —.721 for the normals.

In one experimental situation Kopke had also concealed an interrupted activity and in another experiment arranged to have the substitute completed at a different table so that the subject could not see the incompleted work. Lewin, in discussing Kopke's study, states that the feebleminded child would not be expected to resume in such situations: It is typical of the feebleminded child that he is "totally in one situation or totally in another" (2, p. 188). And the eight feebleminded subjects whom Kopke used showed zero resumption when they were at a different table. With six subjects when the task was concealed, he had one resumption.

We found decreased resumption for the feebleminded in situations where a barrier was present, but we likewise found decreased resumption for our normal subjects of the same mental ages. To

determine whether one group was affected more by the barrier than the other group, it is necessary to remember that the feebleminded subjects resume less than the normals. Therefore the means from the first three experiments are used as standards with which the average means from the barrier experiments are compared. The feebleminded are affected more by the barriers than are the normals, with a decrease of .789 down the scale for the feebleminded and .624 for the normals.

We draw the following conclusions, therefore, in regard to Problems III and IV: Destroying the interrupted activity, hiding the interrupted task, and having the subject finish the substitute in another place from the original uncompleted work are situations in which barriers arise to prevent resumption. The barriers exist for both groups but are of greater strength for the feebleminded.

4. *Problem V*

As the field was cleared of all other materials when a new experiment was started, it was thought that possibly resumption was occurring because there were no other particular activities in which the subject might engage. Experiment 11 was designed to answer this question, and on the table with the interrupted block pattern were placed other materials: a puzzle, clay, paper, scissors, pencil, and a pattern to trace. All of these had at one time been used by the subjects in former experiments.

The records of behavior indicate a high degree of resumption, and the mean scores on the scale in Table 1 of .507 for the feebleminded and .400 for the normals are the highest mean scale values obtained for the lower intelligent group and the third highest for the normal subjects. The behavior of the subjects in response to the other materials on the table was particularly interesting to the experimenter. They did not touch, nor ask questions concerning, nor respond in any manner to the extra materials until after resumption had taken place and the large block pattern finished. Because resumption was so high, Experiment 11 as a *test* of persistency is poor, not differentiating the subjects, with the scores on the test being so uniformly high that the correlations of this test with the other tests were low or minus. But as an answer to the question whether resumption will take place where there are other activities for these subjects, the experiment gives a very positive "yes."

5. *Problem VI: Experiments 12 and 13*

a. The problem. The experimenter was interested in discovering the effect on behavior of an interruption in a series of identical block patterns and then in a series of different patterns.[3] Would the demand for resumption be more compelling with the identical block patterns than for the less unified series?

b. Procedure. Five piles of 11 prearranged blocks were placed before the subject, and in Experiment 12 the experimenter said, *"I am going to make one like this* (showing a pattern outlined on paper) *and then I'll ask you to make five like it."* After illustrating the method of fitting the blocks together, she added, *"Now make five like this,"* and at the same time indicated the model. In Experiment 13 five *different* patterns were to be made. In each series the experimenter interrupted the second pattern when it was one-half completed and told the child to make the next patterns.

c. Results. As soon as the interruption was attempted, various forms of behavior were shown by the subjects. As in the other experiments, they might object to the interruption, either completely or in part. If they did not complete the interrupted second pattern, then they might resume it immediately after finishing the third, or not until completing the fourth, or the fifth pattern of a series. Or they might not resume until after a period of delay, or they might show no resumption whatever, permitting the series to remain incomplete.

No attempt was made to score the subjects in scale values on their records in these last two experiments, in as much as the nature of the set-up was slightly different. However the 120 records of behavior following interruption, obtained in these two experiments with 30 feebleminded and 30 normal subjects, were analyzed and are presented in Table 3. There are no differences between the feebleminded and the normal groups either on the identical series or the non-identical series of patterns. On the identical series it is true that there are more complete-refusal-to-be-interrupted among the normals (12 as contrasted to 1 for the feebleminded) but there are also less immediate resumptions among the normals (5 as contrasted to 17 for the feebleminded after the third pattern). On the non identical series the records of the two groups parallel each other

[3]The two series were separated by an interval of several days

TABLE 3

DISTRIBUTION OF 120 RECORDS OF BEHAVIOR FOLLOWING INTERRUPTION OF 30 FEEBLEMINDED AND 30 NORMAL SUBJECTS IN TWO DIFFERENT ACTIVITIES

(Identical and different patterns made from the same blocks and interrupted at the second pattern.)

Subjects	Patterns	Refused to be interrupted: Complete	Refused to be interrupted: Part	Resumed before finishing third pattern	Immediate resumption: After third pattern	Immediate resumption: After fourth pattern	Immediate resumption: After fifth pattern	Resumption after delay	Tendency to resume	No resumption
F.M.	Identical	1	5	1	17	1	5	2	0	3
	Different	3	2	0	11	0	9	2	0	5
Normals	Identical	12	1	1	5	0	9	2	0	1
	Different	7	2	0	8	0	13	1	0	1
F.M.	Totals	4	7	1	28	1	14	4	0	8
Normals		19	3	1	13	0	22	3	0	2
Combined groups	Identical	13	6	2	22	1	14	4	0	4
	Different	10	4	0	19	0	22	3	0	6

rather closely. Considering the totals for the two groups, we find the normals are slightly superior in their frequencies of those forms of behavior that indicate a stronger tendency-to-continue an activity. This slight superiority is, of course, in line with their performance in the other experiments.

It is interesting to note that when the two groups of subjects are combined, the 120 records include only three more immediate resumptions after the third pattern in the identical series than in the non-identical. Evidently the "need for completion" is not any stronger when the series "hang together" than when the series is composed of different parts. However, the experimenter does not claim that the above is a crucial test of such a suggested problem. Further analysis was made of the individual records of the 60 subjects. Twenty-nine of the subjects behaved alike on the two series. Of the 31 who changed their position—behaved differently on the two series following interruption—23 showed a diminished tendency-to-continue when interrupted in a series of different patterns. (Their behavior in the identical pattern series was used as the standard.)

The conclusions in regard to Experiments 12 and 13 is that (*a*) these two experiments, comparing behavior following interruption in a series of identical as contrasted to non-identical series of block patterns, do not distinguish the feebleminded from the normals, and (*b*) when both groups are considered together there is some slight evidence of a change of behavior in the non-identical series to "weaker" types of persistency than were shown in the identical patterns.

E. Summary

Feebleminded and normal subjects were compared under varying conditions which affect behavior following interruption In 10 of the first 11 experiments the normal subjects were superior to the feebleminded in mean performance as measured on a scale of tendency-to-continue. In two of these experiments the critical ratios indicated that the less intelligent group were significantly lower than the normal subjects.

The behavior of the two groups varied under the different conditions which were set up in each experiment. (*a*) When a substitute was used, the tendency-to-continue an interrupted activity decreased for both groups. Köpke's statement that the feebleminded

are less affected in their resumptions by a substitute than normal subjects was not substantiated. (*b*) The increase of similarity between the substitute and the original activity—a condition which generally decreases resumption—was not effective in consistently decreasing the resumptions of the normals. However the feebleminded did not return so frequently and hence Köpke's statement that in spite of increased similarity between the substitute and the original activity, the feebleminded remained high in resumption was contradicted by our results. (*c*) The setting up of barriers affected both types of subjects with the feebleminded being more affected than the normals. This may be interpreted as supporting Lewin's view that the feebleminded are either in the one or the other situation, or it may be considered as further evidence that the persistency of the feebleminded is less than that of the normals. (*d*) The experiment designed to test the effect of other materials in the field upon resumption gave a very emphatic answer: resumption remained very high in spite of the presence of possibly distracting puzzles, patterns, clay, etc. This was true for both feebleminded and normal subjects. (*e*) In Experiments 12 and 13, designed to determine whether persistency would be stronger in a series of identical, as contrasted to non-identical series, of block patterns, the behavior of feebleminded and normals was similar. There was some slight evidence that when the two groups are considered together the non-identical series called out "weaker" types of persistency than the identical series.

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Department of Psychology
University of North Carolina
Chapel Hill, North Carolina

The Journal of Genetic Psychology, 1941, **59**, 139-153.

SEX DIFFERENCES IN TIMIDITY IN NORMAL AND GONADECTOMIZED RATS* [1]

Department of Psychology, Wilson College

E. E. ANDERSON

A. INTRODUCTION

Somewhat conflicting results have been obtained by various investigators with reference to the problem of sex differences in emotional traits in the rat. Yerkes (15) rated females of the first generation of a wild by tame cross as more savage, wild, and timid than the males of that generation; the second generation males and females, however, showed the opposite relation. Utsurikawa (13), using groups of animals too small to yield statistically significant results, found female rats to be more savage than males, as measured by the biting behavior displayed when a wire was moved about in the cage. The females also showed a more marked response (startle?) to an auditory stimulus. On the other hand, the females came forward in their cage at the approach of the experimenter more frequently than did the males. Coburn (5) rated hybrid females of a wild-tame cross of mice as being more savage and wild than the males. Stone (11), using a composite rating of savageness and wildness, found no significant difference between the males and females of his half-breed group, although there was some tendency for the females to rate slightly higher than the males. Dawson (6) used the speed with which mice ran through a runway as a measure of wildness. This measure clearly differentiated wild from tame mice, the wild animals running in much less time than the tame animals. In the wild groups, the females were reliably faster than the males. With the tame groups, a small difference was in favor of the males rather than the females. In the F_1 and F_2 crosses, the females were again faster (wilder?) than the males, the differences being respectively 2.4 and 2.1 times their standard error.

In general, the results of the above studies would appear to indicate that female rats may be somewhat more savage and wild than

*Received in the Editorial Office on May 4, 1940.

[1]The experimental work reported here was done in Prof K. S Lashley's Laboratory of Physiological Psychology, Harvard University.

male rats, although the evidence is by no means unambiguous. Somewhat in contrast to the above results, Hall (7, 9), using defecation in an open field as a measure of emotionality, has found that male rats are more "emotional" than the females. The conflicting results may, in part, be due to differences in the traits studied, since the studies using rating scales have been primarily concerned with "savageness" and "wildness" while the defecation test used by Hall appears to be more a test of "timidity."

The present experiment was designed to obtain further evidence concerning sex differences in timidity in the rat by comparing the performance of male and female animals upon four different tests of timidity. Gonadectomized animals of both sexes were used in addition to the normal groups in order to control for possible effects of the sex hormones upon timidity

B. Procedure

1. *Animals*

A total of 42 castrated males, 42 normal males, 43 ovariectomized females, and 40 normal females were used in the present experiment. All animals were pigmented.[2] At between 28 and 46 days of age, half of the females and half of the males of a given litter were gonadectomized under deep ether anesthesia and under aseptic conditions, the remaining animals of each litter being placed in the normal groups. The animals were housed (5 per cage) in mesh wire cages measuring 13½ by 12 by 12½ inches and were maintained upon a diet of dog chow supplemented with fresh meat and lettuce. All of the animals of a given cage were of the same sex and same condition (i.e., either gonadectomized or normal). At the beginning of the tests of the present experiment the animals were 112 days old (range 100 to 116 days).

2. *Tests used*

Four measures of emotionality or timidity were used:

a. Open field defecation test (2, 8). The rat to be tested was placed by hand in an open field made of sheet metal 30 inches high which formed a circle 90 inches in diameter. The animal was removed from the field after a test period of three minutes and the number of fecal boluses excreted was recorded A retest was given

[2]These are the animals used in a castration study previously reported (3)

four days later.[3] The score is the total number of fecal boluses excreted in the two tests given, it being assumed that a low defecation score indicates a low degree of timidity. The animals were 112 days old at the first open field test.

b. Water-wading defecation test (2). The rat to be tested was placed in a bottomless sheet metal box 12 by 10 by 13 inches high which was placed in a pan containing 1¼ inches of water. A sheet metal sliding door on the top of the box was used to introduce the animal into the compartment and to prevent escape by jumping. The animal was thus wading in water in a dark box with no means of escape. After three minutes in the box, the rat was removed and the number of fecal boluses excreted was recorded. It is assumed that a low defecation score indicates a low degree of timidity. The test was repeated daily for six days and the score is the total number of fecal boluses excreted in the six tests. The animals were 117 days old at the first water-wading test.

c. Emergence from living cage test (2). The living cages used were made of mesh wire of the dimensions previously given. In the center of the top of the cage was an opening 7 by 5 inches. The opening was not closed by a door, but escape was prevented by pushing the cage between supporting shelves. For the present test, the cage was pulled out from the shelves far enough to allow the rats free egress from the cage. By climbing up the wire sides of the cage, the rats could escape through the opening in the top. A stop watch was started when the cage was pulled out and the time recorded when a rat came out on top of the cage. As an animal emerged it was picked up and placed in another cage until all of the animals of a given cage had thus emerged, or until the test was discontinued in the event that some rats failed to come out. The test continued for 20 minutes and if an animal had not come out of the cage during this period it was given the maximum score of 20 minutes. The test was repeated four times with an interval of one day between tests. The score is the total time required to emerge from the cage for the four tests, it being assumed that rats which take a long time to emerge are relatively more timid. The animals were 133 days old at the first emergence from cage

[3]It is ordinarily desirable to repeat the open field test several times to increase reliability In the present experiment, the number of animals not defecating on the second test was so high that further tests with the open field appeared to be of little value.

test. Not all of the animals were given the cage test, the number tested being indicated in the tables.

d. Emergence from stovepipe test (2, 11). The rat to be tested was placed in a small starting box and allowed to enter a dark U-shaped tunnel made of 4-inch stovepipe. The total length of the tunnel was 72 inches. The animal was required to run through the dark tunnel and emerge into a day-lighted exit box which contained several more or less preferred foods (sugar, meat, wet mash). The animals were not hungry when tested. If the animal had not entered the exit compartment within five minutes it was removed from the apparatus by separating the stovepipe sections and given the maximum score of five minutes for the trial. Four trials, one every other day, were given. The score is the total time (for four trials) required by the animal to go from the starting box to the exit box. It is assumed that rats which stay in the tunnel a long time are relatively more timid. The stovepipe test was given to a partial group of gonadectomized animals only. The rats were 138 days old at the first trial in the tunnel.

3. *General conditions of testing.* The animals were never under conditions of food or water deprivation when given any of the above tests. They were merely taken from their living cage, which always contained food and water, and tested. To avoid the possibility of odors from animals of one sex influencing the performance of animals of the opposite sex, the apparatus was duplicated for the above tests so that the male and female animals were not tested upon the same apparatus.

C. Results

1. *Open Field Defecation Test*

The results obtained with the open field defecation test are pre-

TABLE 1

COMPARISON OF MALE AND FEMALE RATS UPON THE OPEN FIELD DEFECATION TEST

Scores are in terms of the total number of fecal boluses excreted in two 3-minute periods.

	Males			Females			Difference		
	N	Mean	σ_M	N	Mean	σ_M	M-F	$\sigma_{diff.}$	D/σ_D
Normal	42	5.98	.84	40	3.23	.87	2.75	1 21	2.27
Gonadectomized	42	6.74	.84	43	3.84	.80	2.90	1.16	2 50
Combined group	84	6.36	60	83	3.54	.59	2.82	0.84	3.36

sented in Table 1. All differences show that emotional defecation is less for the females than for the males in either normal or gonadectomized animals. The critical ratio (D/σ_{diff}) for the normal groups is 2.27, for the gonadectomized animals it is 2.50. Since no significant differences were found between gonadectomized and normal animals (3), and since the standard deviations are approximately the same, the gonadectomized and normal groups have been combined. With the combined groups, the difference between the male and female animals is 3.36 times its standard error. This result clearly confirms Hall's (7) finding that female rats defecate less in an emotional situation than males. A similar result is obtained if the number of animals not defecating is considered. With the combined male groups a total of 168 observations (84 rats, each tested twice) were made in the open field. Zero scores, i.e., no defecation, were recorded in 65 of these observations; thus 39 per cent of the male scores were minimum. With the combined female groups, 69 per cent (114 of 166 observations) of the tests were cases of no defecation. The difference between the percentages of the male and female groups is 5.77 times its standard error and is clearly significant.

2. *Water-wading Defecation Test*

The results for this test are presented in Table 2. As with the

TABLE 2

COMPARISON OF MALE AND FEMALE RATS UPON THE WATER-WADING DEFECATION TEST

Scores are in terms of the total number of fecal boluses excreted in six 3-minute test periods.

	Males			Females			Difference		
	N	Mean	σ_M	N	Mean	σ_M	M-F	$\sigma_{diff.}$	D/σ_D
Normal	42	29.86	2.08	40	25.51	2.46	4.35	3.22	1.35
Gonadectomized	42	28.36	2.17	43	23.18	2.60	5.18	3.39	1.53
Combined group	84	29.11	1.51	83	24.29	1.80	4.82	2.35	2.05

open field defecation test, the females are again less timid (i.e., defecate less) than the males. The differences are consistently in favor of the female groups, both normal and gonadectomized, but are not statistically significant. When the gonadectomized and normal groups are combined, the difference is 2.05 times its standard error. It is possible that the smaller difference between the sexes

found in the water-wading test as compared with the open field test may be due, in part, to the fact that the water-wading situation appears to arouse a stronger emotional response than the open field. Since there is a limit to the amount of fecal material present in an animal, a situation which evokes a near maximal emotional response would be expected to show a somewhat smaller sex difference. The difference in favor of the female group becomes clearer when the per cent of animals yielding zero scores is considered. A total of 504 observations (84 animals each tested 6 times) were made upon the male animals. Of these, 102 or 20 per cent were cases of no defecation. With the combined female group, 36 per cent (177 of 498 observations) were instances of no defecation. The difference between the percentages of the male and female groups is 5.46 times its standard error.

3. *Emergence from Living Cage Test*

The results for this test are presented in Table 3, and clearly

TABLE 3

COMPARISON OF MALE AND FEMALE RATS UPON THE EMERGENCE FROM LIVING CAGE TEST

Scores are in terms of the total number of minutes to emerge from the cage in four tests of 20 minutes each.

	Males			Females			Difference		
	N	Mean	σ_M	N	Mean	σ_M	M-F	σ_{diff}	D/σ_D
Normal	30	58.32	3.80	30	22.73	4.44	35.59	5.84	6.09
Gonadectomized	32	53.70	4.18	33	35.66	4.16	18.04	5.90	3.06
Combined group	62	55.94	2.85	63	29.50	3.14	26.44	4.24	6.24

show that the female rats emerge from the living cage in less time than do male rats. All differences are significant and in favor of the female rats whether normal or gonadectomized.

4. *Emergence from Stove-Pipe Test*

This test was given to a partial group of the gonadectomized animals only. The results are presented in Table 4. The female rats again receive lower timidity scores upon the test, but the difference lacks complete statistical significance, possibly because of the small size of the groups involved.

TABLE 4

COMPARISON OF MALE AND FEMALE RATS UPON THE EMERGENCE FROM STOVE-PIPE TEST

Scores are in terms of the total number of minutes to emerge from the stovepipe in 4 tests of 5 minutes each.

	Males			Females			Difference		
	N	Mean	σ_M	N	Mean	σ_M	M-F	σ_{diff}	D/σ_D
Gonadectomized	32	11 72	1 13	33	8.95	1 13	2 77	1 60	1.73

5. *Variability*

A comparison of the standard deviations of the total scores for the male and female groups is presented in Table 5. None of the tests yields sex differences in variability which are statistically significant. Since the mean scores of the female groups are lower than those of the male groups and the standard deviations are approximately the same for the two sexes, it follows that the relative variability of the female scores is somewhat greater than that of the males. In general, the range of the scores for the female rats is as

TABLE 5

COMPARISON OF THE VARIABILITY OF NORMAL AND GONADECTOMIZED MALE AND FEMALE RATS UPON FOUR TESTS OF TIMIDITY

The values presented are for the total scores of each test. The defecation tests are scored in terms of the number of fecal boluses excreted; the emergence tests in terms of minutes to emerge.

Group	Male			Female			Difference		
	N	SD	σ_{SD}	N	SD	σ_{SD}	M-F	$\sigma_{diff.}$	D/σ_D
Open field defecation test									
Normal	42	5 43	.59	40	5.51	.62	—0.08	.86	—0.09
Gonadectomized	42	5 46	.59	43	5 22	.57	0.24	.82	0.29
Combined group	84	5.46	.42	83	5.37	.42	0 09	.59	0.15
Water-wading defecation test									
Normal	42	13.51	1.47	40	15.55	1 74	—2.04	2.28	—0 89
Gonadectomized	42	14.09	1.53	43	17.02	1.84	—2 93	2 39	—1 23
Combined group	84	13.83	1.07	83	16.37	1.27	—2 54	1 66	—1.53
Emergence from living cage test									
Normal	30	20.79	2.69	30	24.32	3.14	—3.53	4.13	—0.85
Gonadectomized	32	23.65	2.96	33	23.90	2.94	—0.25	4.17	—0.06
Combined group	62	22.43	2.02	63	24.96	2.22	—2.53	3.00	—0.84
Emergence from stovepipe test									
Gonadectomized	32	6.39	.80	33	6.52	.80	—0.13	1.13	—0.12

great as that for the males, but the distributions of the female scores tend to be more skewed, with more females making low scores than is the case with the males.

D. Discussion

The female animals, both normal and gonadectomized, make lower mean scores upon all four tests than do the male rats. Several interpretations of the lower female scores are possible. The five interpretations to be considered in this discussion are: (*a*) Female rats are considerably lighter in weight than are male animals. This difference in body weight plus sex differences in metabolism, etc., may result in the females containing a smaller amount of fecal material than the males. A lower female score on defecation tests might then result. (*b*) The lower female scores on the defecation tests might be due to the existence of a sex difference in visceral excitability. If the female threshold of excitability were higher, a lower defecation score would result. (*c*) The lower female score might be due to a greater, rather than a lesser, degree of timidity in the female animals. This explanation would assume that low defecation scores indicate a high degree of emotional response, presumably due to an over-contraction of the sphincter muscles and the resulting "constipation effect."

Since the two *emergence* tests do not depend upon defecation scores, the above three interpretations are not applicable to them. The emergence tests, however, may be influenced by the general activity level of the animals. (*d*) The lower time scores made by the females upon the emergence tests may therefore be due to a higher activity level of the female rats. (*e*) Finally, the lower scores of the female rats on both the defecation and emergence tests may be accounted for in terms of a sex difference in timidity, the female animals being less timid than the males. In the following discussion of the above interpretations, an attempt will be made to show that this fifth interpretation in terms of a sex difference in timidity is the most adequate.

1. *The Amount of Fecal Material Theory*

If it is assumed that the female rats contain less fecal material than the males because of the lower body weight of the females, there are two lines of evidence opposed to this interpretation. (*a*) Hall (7) has found that the sex difference persists even when the

lightest weight males are compared with the heaviest females, the two groups having an equal average weight. (*b*) Using male rats, the writer (1, 4) has obtained correlations between body weight and defecation scores for three different groups of animals. None of the correlations was statistically significant (the values ranged from —.23 to —.28) but the signs were consistently negative. Thus even if heavier animals may contain more fecal material, they do not necessarily defecate more than lighter weight rats in the emotional situations used. If it is assumed that the female rats contain less fecal material than the males, but that this difference is due to factors other than the sex difference in body weight, two further arguments against this interpretation may be made. (*c*) If the sex difference upon the open field defecation test is attributed to the fact that the females do not contain enough fecal material to yield a score as high as the males, then one would not expect a more strongly exciting situation (the water-wading test) to result in an increase in defecation score. Actually, the females average 4.04 boluses per test in the water-wading situation as contrasted with an average of 1.77 boluses per test in the open field situation. (*d*) It was previously pointed out that there is a significantly higher percentage of females making zero scores than males. If the sex difference in defecation score is attributed to differences in the amount of fecal material contained, it would appear to be necessary to assume that such females contained no fecal material for discharge. It can readily be shown that fecal material is usually present in animals not defecating upon any given test. A slight pressure with the fingers in the anal region of the animal is usually sufficient to force out one or two boluses if fecal material is present. In 95 cases of no defecation in female rats such a test was made at the conclusion of the regular test period. In 90 of these cases fecal material was proven to be present. In similar tests upon 30 cases of zero defecation scores in the male rats, fecal material was demonstrably present in 25 animals.

2. *The Visceral Excitability Theory*

If the threshold of visceral excitability of female rats is higher than that of males, then lower female scores upon defecation tests would be expected. Unfortunately, it does not, at present, appear possible to test this theory directly. At best, the theory can account for the results of the defecation tests only and does not apply to

the emergence tests. The visceral excitability theory would thus be somewhat inadequate and would necessitate the assumption of a second factor or principle to account for the results of the emergence tests.

3. *The "Constipation Effect" Theory*

It might be argued that a low defecation score is the result of over contraction of the sphincter muscles and indicates a high, rather than a low, degree of timidity. The lower scores of the females would thus be interpreted as being due to a higher degree of timidity. This explanation appears improbable since Hall (7, 9) has not found any clear evidence that such a "constipation effect" occurs in rats. Nor has the writer found any clear evidence of such an effect. Furthermore, two arguments from the present data indicate that such an effect does not occur, or, if it does, is too rare to have a distorting effect upon the results. (*a*) If failure to defecate upon a given test is a result of strong emotional excitement, then a more exciting situation (emotionally) ought to yield more zero scores than a less exciting one. Specifically, the water-wading situation ought to yield more zero scores than the open field test. As Table 6

TABLE 6

SHOWING THE PER CENT OF ANIMALS *Not* DEFECATING UPON EACH TEST OF THE OPEN FIELD AND WATER-WADING DEFECATION TESTS

Gonadectomized and Normal Groups Have Been Combined.

Test number		Open field test		Water-wading test					
		1	2	1	2	3	4	5	6
	N	%	%	%	%	%	%	%	%
Males	84	32	45	0	2	23	21	36	39
Females	83	63	75	7	25	35	43	51	52

shows, the opposite is true, i.e., the per cent of animals making zero scores is much higher for the open field test than for the water-wading test. (*b*) Again assuming that a low score is the result of a strong emotional stimulation, one would expect a greater frequency of zero scores upon the first test of a given situation than upon the later tests when adaptation has taken place. As Table 6 shows, the opposite is true, i.e., zero scores become more frequent as the test is repeated and adaptation to the situation occurs. Low scores on the defecation test thus appear to be an indication of a low degree of emotionality or timidity, and they tend to occur most frequently

in mildly exciting situations and after emotional adaptation to a given situation has occurred.

Apart from the specific criticisms made above, the preceding three theories all apply to the defecation tests only and would thus necessitate the assumption of a second factor to account for the lower female scores on the emergence tests. Such a factor might be found in the sex difference in activity level.

4. *The Activity Level Theory*

It is quite probable that scores made upon the emergence-from-cage and stovepipe tests may be influenced by such factors as general and exploratory activity. Since normal females tend to be more active than normal male rats, it might be argued that the lower female score upon the emergence from cage test was due to the greater activity of the female rats as compared with the males. The use of the gonadectomized groups, however, would appear to be an adequate control upon this possibility. The lower female scores persist even in the gonadectomized groups and it is to be noted that the ovariectomized females make a lower score upon the emergence-from-cage test than do the *normal* males, although normal males are expected to be more active in revolving drums than ovariectomized females. These facts appear to rule out the possibility that the results of the emergence tests can be accounted for in terms of the sex difference in activity. That activity level may play some part in the emergence from cage test may be indicated by the fact that the sex difference is greater in the normal groups than in the gonadectomized groups, but the important point here is that a significant sex difference is still obtained with the gonadectomized groups.

5. *The Timidity Theory*

The lower female scores upon all four tests can be readily accounted for upon the basis of a sex difference in timidity, the female animals being less timid than the males. The present theory thus has the advantage of supplying a uniform principle which accounts for the results of all of the tests rather than being limited to one type of test only. Furthermore, a considerable body of evidence concerning the validity of such tests as those used here as measures of emotional responses has been accumulated. Hall (8) has presented evidence and arguments concerning the validity of the defecation

tests. Further evidence may be found in the relations of the defecation test to measures of other traits (1). Stone (11) and Vaughn (14) have presented evidence which concerns the validity of the stovepipe test. Finally, the writer (2) has shown that the four tests used in the present study yield significant intercorrelations. In general, then, the most adequate interpretation of the results appears to be that female rats are less timid[4] than the male animals.

6. *Comparison with Other Studies*

The results of the present study are in essential agreement with several other studies involving measures of timidity. Hall (7, 9) has reported that females make lower scores than males upon an emotional defecation test. In Utsurikawa's (13) study, one test (coming forward in the cage at the approach of the experimenter) is similar to the emergence from cage test of the present experiment. The number of animals used was too small to yield significant results, but the females tended to come forward more frequently than did the males. This finding is in agreement with the evidence of the present study. Yerkes (15) included a rating of timidity in his study but expressed some doubt as to the feasibility of differentiating timidity from wildness and savageness by means of ratings. His results were inconsistent for the two generations studied, the F_1 females being somewhat more timid than the F_1 males while the F_2 females were less timid than the F_2 males. With the exception of Yerkes' study, then, the results have been consistent in pointing to a lesser degree of timidity in the female rat.

With regard to savageness and wildness,[5] the majority of the studies summarized in the introduction to this paper find some tendency for the female to be more savage and wild than the male, although the differences, in most cases, are not large enough to be statistically significant. It is possible that some of the inconsistency in the results has arisen because savageness is confused with timidity

[4]Hall (7, 8, 9) has used the term emotionality in referring to the results of the defecation tests. The writer has used both emotionality and timidity but now favors the latter because it appears to be desirable, at present, to differentiate emotional responses of the aggressive or fighting type from those of the shrinking or timidity type. If future experimentation should show these two types of emotional responses to be closely related, the more general term of emotionality may become preferable.

[5]The difference between savageness and timidity has been well stated by Yerkes: "A savage and aggressive wild rat fights, whereas a timid rat cowers, trembles, and chatters" (15, p. 288).

in making ratings. If the somewhat general tendency of the female to rate slightly more savage and wild than the male may be taken as an indication of a slight, but true, sex difference, then some negative relation between the aggressive types of emotional reaction (savageness and wildness) and the timidity type of reaction may be indicated. Such a negative relation might possibly arise from differential action of the sympathetic and parasympathetic nervous systems. Kling (10) has suggested that anger or fighting fear may depend primarily upon sympathetic action whereas the timidity type of fear reaction appears to involve parasympathetic action. On the other hand, the studies using rating scales have dealt primarily with wild or half-wild rats, whereas the studies using defecation tests, etc., have been confined to tame stocks. It is therefore possible that the evidence, instead of indicating a negative relation between savageness and timidity, might suggest that the sex difference in emotional reaction may differ in wild as compared with tame stocks. It should be noted, however, that the animals of the present study are pigmented and were originally derived from a mixture of wild and tame stocks. But the present animals are typical of tame laboratory stocks and cannot be characterized as "wild."

The present study concerns the emotional responses of the two sexes before marked adaptation to the test situation has occurred. Hall (7) found the difference in favor of the females to be much greater in the first three days of testing than in later tests. It is therefore possible that male animals are initially more timid than females but they adapt more rapidly than do the females. If such were the case, the sex difference could be expected to disappear in later tests, and conflicting experimental results might be due to the differences in the stage of adaptation at which the animals were tested.

7. *Nature versus Nurture*

It would appear probable but not as yet certain, that the lower timidity level of the female is due to innate factors. Hall (9) has presented evidence that the general level of emotionality is inherited but it would still be possible for the sex difference to be influenced by environmental factors. Since living cages and general environmental conditions are constant for the two sexes in the present study, the most probable source of differential environmental influence

would appear to lie in possible differences in social reactions of the two sexes. In the present experiment, only animals of the same sex were caged together. Uhrich (12) has reported that fighting is less frequent among female mice caged together than among male mice when caged together. If fighting and the resultant emotional excitement tends to increase the general emotional level, especially of those animals which receive the worst of the battle, then male rats might be expected to become more emotional or timid than females. It does not appear probable to the writer that the sex difference in timidity in the rat can be attributed to such a factor, but the evidence at present is not adequate for a final decision. Against the interpretation of the sex difference in timidity being due to a sex difference in frequency and intensity of fighting is the fact that Uhrich (12) also found some decrease in fighting in castrated males. But castrated males are not less timid than normal males (3). If the sex difference in timidity is due to the possibly greater frequency of fighting among male rats, certain implications should follow: (*a*) No sex difference in timidity should be found among animals raised in complete isolation. (*b*) The difference between the sexes should be less or disappear in young animals, i.e., before fighting occurs. These implications have not been tested.

If the sex difference in timidity in the rat should prove to be innately determined, the most probable source of the difference would appear to be in sex differences in the function of the autonomic nervous system or in the function of some one or more of the endocrine glands. Since the present study has shown that the sex difference in timidity is not changed by gonadectomy, the gonadal hormones can be eliminated as a possible source of the difference.

E. Summary

1. Groups of 30 to 40 male and female rats were given four tests of timidity.

2. Upon all tests used, the female rats are less timid than the male rats.

3. Gonadectomy before puberty does not effect the sex difference in timidity.

4. Although the sex difference is probably innately determined, present evidence does not rule out the possibility that the difference may arise as a result of a sex difference in social factors associated with the common laboratory practice of segregating, but not isolating, the animals according to sex.

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Department of Psychology
Wilson College
Chambersburg, Pennsylvania

The Journal of Genetic Psychology, 1941, **59**, 155-175

NEURO-MOTOR MATURATION OF ANTI-GRAVITY FUNCTIONS AS REFLECTED IN THE DEVELOPMENT OF A SITTING POSTURE*

Normal Child Development Study of the Department of Pediatrics, Columbia University and the Babies Hospital

MYRTLE B. MCGRAW

A. INTRODUCTION

A series of studies of the neuro-motor development of the human infant has been conducted for the purpose of ascertaining changes in motor function which reflect development in neural organization. Several of these studies (4, 5, 6, 7, 8, 9) have already been reported. As was pointed out in the earlier reports it is premature to attempt to establish a correlation between behavior development and a specific neuro-structural counterpart. On the other hand the possibility of rating selected behavior activities as predominantly of two distinct neural levels, viz., (*a*) subcortical or (*b*) cortical, and determining the periods of major transition from one level to the other has been demonstrated. By allocating the period during which these gross changes take place a basis for more detailed analysis of neuro-structural functioning becomes available.

The present report concerns changes in behavior which reflect advancing organization of the neural structures which govern anti-gravity muscles, particularly those employed in the assumption and maintenance of a sitting posture. The newborn infant offers little resistance to gravitational forces, but at some time, usually during the third quarter of the first year of life, he gains the ability not only to resist the force of gravity sufficiently to maintain an erect sitting position but also to overcome the force in order to assume independently a sitting position. In order to study the nature of the development which culminates in the infant's independent and coördinate assumption of a sitting position, it was found convenient to pull the child by the hands from a recumbent to a sitting position and then gently push him forward so as to test his growing resistance and sense of balance. By this method it was possible

*Received in the Editorial Office on May 10, 1940.

to detect neuro-muscular development before the child was able to gain an independent sitting position.

The data for the present analysis consist of 1,717 observations upon 82 infants ranging in age from birth to 800 days. Of this total 1,192 records were in the nature of written protocols and 525 were recorded on 16 mm. motion picture film. A total of 4,450 feet of film was exposed in making the records. In order to obtain longitudinal data on the development of the same activity intensive observations were recorded daily (four or five days a week) on four additional infants during the first 400 days of life.

In analyzing the records it has been convenient to consider in separate categories (*a*) the muscular coordinations evinced during the movement of the trunk from the recumbent to the sitting position, and (*b*) movements and postural adjustments which occur after the axis of the body has reached a vertical position with respect to the underlying surface. Within this framework it has been possible to define five phases of developmental import manifested during the rising movement, and six significant phases which exemplify advancement toward the maintenance of a sitting posture. As in the previous studies the qualifying features of each phase have been those which denote neural maturation, and are, therefore, those common to most infants without regard for individual peculiarities. Although the data were collected and recorded in terms descriptive of the movements involved long before the developmental phases were defined, it was possible later to allocate each observation to the phase most representative of the behavior. To render the observational data to a symbolic system, plus ratings were assigned to the phase representative of the stage of development described. This system of rating is the same as the one used in other studies (4) previously reported. The basis for the rating of each observation of this particular behavior item will be clarified by the following detailed descriptions of the qualifying features of each phase.

B. Criteria Used in the Selection of Developmental Phases

1. *The Rising Aspect*

The first analysis concerns the change in posture and movements involved in raising the trunk counter to the force of gravity.

a. The newborn or passive phase. The newborn infant manifests practically no resistance to gravitational force. When, by trac-

tion on the upper extremities, he is pulled from a recumbent position to a sitting posture, this passive state is indicated by the head dropping back toward the inter-scapular spine; when he is brought into the sitting position the head flops over so that the chin rests on the chest. Any flexion of the upper or lower extremities is noticeably tonic rather than deliberate, and arching of the spine which often occurs during the rising movement is a result of the head dropping backwards rather than deliberate spinal extension. Some newborn babies are more hypertonic than others, so care must be exercised in rating such infants lest their general tonicity be given developmental value. A plus rating has been assigned to this phase when no definite tension of trunkal muscles which would indicate an effort on the part of the baby to facilitate the rising movement is detectable. This phase is represented by the line drawing 1*A* for Figure 1.

b. Orthotonic phase. Within a few weeks after birth it is observed that the baby is no longer quite so passive when being pulled into the sitting posture. Advancement in control of the cervical region is evinced during the rising movement by the head being held predominantly in the axis plane. At the incipient stage of this phase the head may drop back toward the end of the rising movement, but as development advances it is maintained in the body plane during the entire distance. There is, however, no appreciable effort on the part of the baby to aid in pulling forward, and ordinarily the lower extremities remain flexed, abducted at the knees, and inactive. This stage of development is illustrated by the line drawing 1*B* of Figure 1. Plus values were ascribed to both Phases 1*A* and 1*B* on occasions when the child could not maintain the cervical control throughout the entire movement.

c. Voluntary flexor phase. As development proceeds it is noticed that the child is not only able to maintain his head in the axis plane, but that he further flexes the head forward, shows some flexion of the trunk, deliberately draws the lower extremities on the abdomen and gives aid in pulling his body from the recumbent to the sitting position. Line drawing 1*C* of Figure 1 illustrates this phase of development. It covers a comparatively long period and builds up to its full strength gradually. In the very beginning it will be observed that the child flexes the neck, bringing the chin forward, and perhaps flexes the lower extremities toward the abdomen but does little distinct pulling on his own part. Later considerable effort is

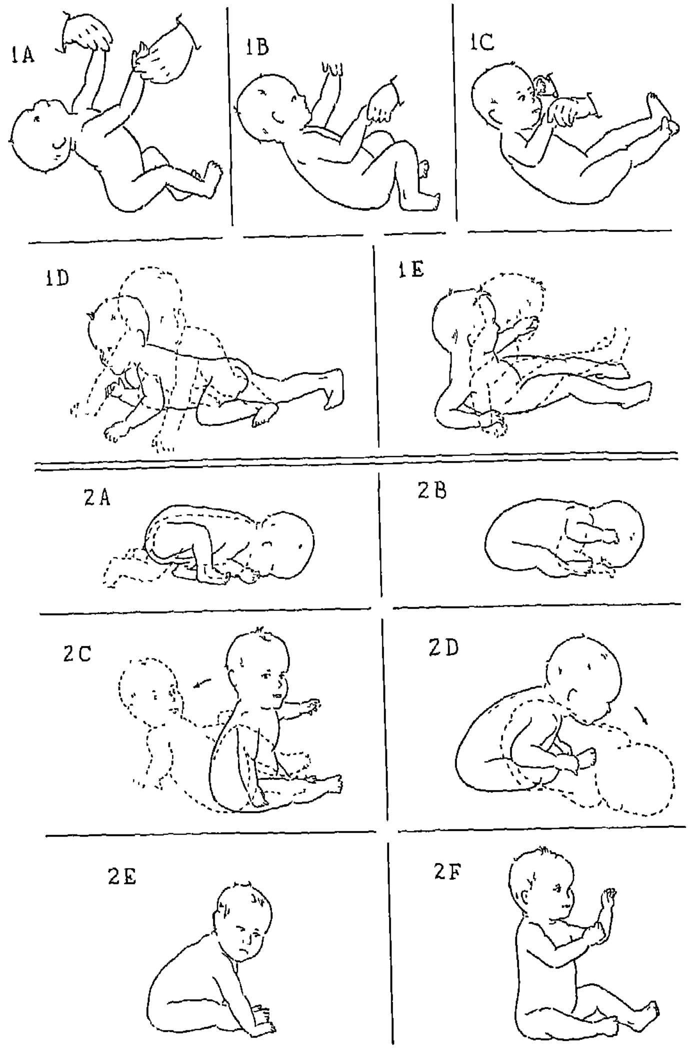

FIGURE 1

Line Drawing Illustrating Five Phases of the Rising Aspect and Six Phases of the Resistive Aspect of Neuro-Muscular Development in Achieving a Sitting Position

expended by the baby in participating in the rising movement provided the experimenter minimizes his own efforts and depends upon the infant to exert himself. Subsequently the experimenter will find it necessary to lend only supporting fingers, and with such slight aid the infant will do most of the work involved in raising his body upward. Furthermore, about this time it will be observed that the baby expends much less effort in effecting the movement than was necessary a few weeks earlier; the general trunkal flexion will be noticeably less and there occurs less elevation of the lower extremities toward the abdomen. That the child is advancing more toward the stage of independent assumption of a sitting posture may be reflected an abortive attitude of resistance toward being pulled by the experimenter. At this time the child may deliberately drop the head backward, or attempt to draw the hands away from those of the adult. Advancement toward independent action is also evidenced by a transitory tendency to turn the shoulder slightly sideways during the rising movement, as if expressing an incipient urge to roll prone as a factor in the assumption of the sitting position. In order to demonstrate the overlapping and gradual emergence of one phase from the other a plus rating has been ascribed to Phases 1*B* and 1*C* when the child showed some degree of flexion and elevation of the lower extremities but no noticeable effort or pulling on his own part; to 1*C* only when he exercised distinct effort to facilitate the rising movement; and to 1*C* and 1*D* when he began to turn the shoulders to one side but was unable to assume the sitting position independent of aid.

d. Ventral-push phase. The two following phases have been defined in terms of the pattern of the movement involved in the independent assumption of a sitting position. The division was necessary because the original observations were recorded in this manner, but in fact distinctions drawn exclusively on the mode of movement in this instance somewhat obscure the fundamentals of the developing process which occurs between the inception and the perfection of the ability to rise from a reclining to a sitting position without aid. The defining features should be those which differentiate without regard for pattern between a series of incoördinate, staccato movements and smoothly integrated movements. This manner of differentiating phases was not adopted because, as stated above, the original observations were recorded in terms of pattern form.

It is true that most infants, but by no means all, at the inception

of independent action in this behavior, show a tendency to initiate the behavior by rolling from a supine to a prone position; from the prone position they get into a palm-knee or tripedal position and then abduct one flexed lower extremity as they raise the trunk upward. This method has been classified as Phase 1*D* and is illustrated by the appropriate line drawing in Figure 1. As the babies advance in the ability to get into a sitting position, many of the circuitous extravagant motions are eliminated, and a more direct movement is adopted. This change in pattern and integration is not a sudden development, however. For a time, the child will continue to rotate his body prone, but he is on his hands and knees almost by the time he gets his body turned, so his abdomen does not actually lie on the surface. Later he turns only half way, touches the surface with the opposite hand after he has begun to push upward with one arm. Such instances have received a plus rating in both Phases 1*D* and 1*E*.

e. The dorsal-push phase. As the infant's movements in the assumption of a sitting position become more direct and better integrated it is obvious that he eliminates the round-about method of rolling into a prone position before pushing himself upward. He merely turns slightly to one side, pushes against the surface with one arm, raises the lower extremities a little above the underlying surface, and in seemingly one integrated movement is sitting erect. This phase is illustrated by the line drawing 1*E* in Figure 1. As a matter of fact some infants use this method at the inception of independent sitting, but in such instances the movements are isolated and labored. It has also been observed that most infants who use this dorsal-push method at the inception of independent sitting revert for a period to the ventral-push method later. It seems that such variations in the manner of achieving an independent sitting position at the beginning of development reflect individual peculiarities as to the order in which neuro-muscular pathways are matured. That is, in some infants the ability to oppose the attraction of gravity develops more forcefully than the ability to turn from a dorsal to a prone position.

2. *The Resistive Aspect*

Adjustments in this situation represent quite a different set of neuro-muscular mechanisms from those employed in the rising aspect. In the rising situation the baby must move his body against the force

of gravity whereas here he is called upon only to resist such force. Development of the resistive aspect of the behavior is reflected by changes in bodily positions and movements which occur after the trunk has reached a vertical position with respect to the underlying surface. Six different phases are fairly well differentiated in the development of this aspect of the behavior pattern.

a. The newborn phase. When the body of the newborn infant is pulled slightly beyond the vertical angle with respect to the surface, he exercises no appreciable resistance to gravitational force and falls forward so that his face rests on the surface near his feet. Although he apparently does not find the position particularly uncomfortable, he will often (especially after the first few days of life) engage in movements which elevate the pelvis and extricate the lower extremities pinnioned beneath his body. These movements seem to be relatively localized to the muscles of the pelvic region and lower extremities. They are especially common to the hypertonic infant. A plus rating has been assigned to this phase whether the flaccid infant remains in the hyperflexed position or the more active hypertonic one liberates his legs. The phase is illustrated by the line drawing *2A* of Figure 1.

b. The incipient resistive phase. Within a few weeks it will be observed that the infant shows a fleeting resistance to the fall forward. As the axis of the body passes beyond the right angle there may occur a few jerks back and forth, and when he finally falls forward until his face is near the surface he is apt to express discomfort by crying. His initial efforts to free himself are primarily movements in the shoulder girdle, and he may move the shoulders forward enough to liberate the lower extremities. In general he has great difficulty freeing himself from the hyperflexed position. Sometimes there is sufficient general tonicity so that the lower extremities become extended as he falls forward. In any event it is evident that the infant does not have the freedom of action in the lower extremities which characterizes the newborn phase. This phase is illustrated in Figure 1 by the line drawing *2B*.

c. Exaggerated resistive phase. Subsequently the resistance to falling forward becomes exaggerated though the infant cannot maintain balance for any appreciable time. As soon as he is pulled into the sitting position he shows a tendency to push backwards into the dorsal position. Sometimes the resistance is so marked that only with considerable pressure can the child be forced into the forward

position. Often on occasions when he has been forced into the hyper-flexed position he will with one spinal extensor-thrust throw his body backward and fall into the dorsal position; at other times the resistance may be sustained only to a certain angle, after which the child will revert to the position characterized as Phase 2*B*. Instances when the resistance was indicated but not persistent were rated plus in both Phases 2*B* and 2*C*, but when the tendency to fall backward into the dorsal position was marked then only Phase 2*C* was given a plus rating. This phase is represented in Figure 1 by the line drawing 2*C*.

d. Trunkal resistive phase. In the subsequent phase the infant moves forward from the vertical position and remains for a few moments in a hyper-flexed position, though he does not flex so completely as in Phase 2*B*. Although the angle of flexion may be fairly wide, it remains obvious that trunk muscles are most actively engaged in maintaining the posture. Even though the upper extremities may rest upon the underlying surface they are not actively engaged in supporting the shoulders. Finally the child topples forward or to one side. Line drawing 2*D* of Figure 1 illustrates this phase of the development.

e. Sustained resistive phase. Further advancement toward the sitting posture is clearly indicated when the child is able to maintain the leaning posture, as he supports himself on the extended upper extremities. The angle of flexion varies from time to time and the length of time before falling over also gradually extends. As development proceeds the angle of flexion widens and it is evident that the child depends less and less upon the supporting aid of the upper extremities. This period is represented by the line drawing 2*E* of Figure 1.

f. The independent sitting phase. Mature development in this activity has been defined as that period when the infant can maintain an erect sitting position on a flat surface, usually with one of the lower extremities flexed and abducted while the other is extended from the hip in front of the body. The arms are free to engage in other movements. The position of the lower extremities widens the base and aids in the maintenance of equilibrium. Ordinarily an infant can maintain an erect sitting position when placed on a flat surface before he can sit with the knees flexed over an edge while the feet rest on a lower level. The baby does not achieve the ability to sit erect suddenly. There will be periods when he may rest his

weight on his arms during most of the time, but raise them occasionally. There will also be occasions when he characteristically sits with his hands resting on the underlying surface, or more frequently on the thighs, though he is not actually depending upon them for support. Such instances represent the transition from Phase *2E* to *2F* and accordingly have been rated plus in both classifications.

C. Analysis of the Data

Ratings on all of the observational and cinema records in accordance with the above criteria were used to calculate for the group the age period when each phase, as defined, is the most characteristic mode of behavior in this activity. The curves in Figure 2 show the percentage of children who were, within any given 10-day interval of chronological age, given a plus rating in a particular phase. The number of observations recorded during each 10-day interval is shown in Table 1. The increasing variability manifested in Phases *1D* and *1E* can be attributed to several factors, not the least of which appears to be the criteria used in differentiating the two phases. It was pointed out above that the criteria were limited to descriptions of the movements involved in the independent assumption of a sitting position without the support of an interpretative rationale as to the neuro-muscular development involved. The basic elements of development in voluntary neuro-somatic activities are in essence those which have to do with the degree of integration involved in the various movements rather than the form of the movements per se. A child may develop a fairly integrated system while still employing the ventral-push technique, and certainly the infants who use the dorsal-push method at the inception of independent sitting do not at that time manifest an optimum degree of integration. Also, as is evident in the table, the number of observations at the upper end of the age scale is noticeably smaller than during the earlier phases. Finally, as has been shown in other studies, when an infant gains advanced control of any particular activity any one of a variety of methods may be utilized. To put it briefly, deliberate movements are subject to greater variation than are those controlled at a segmental level.

The unsmoothed curves in Figures 3 and 4 show the age periods when each phase, as defined, was most characteristic of the behavior of four individual infants. These data were obtained by daily observations (four or five days a week) and the curves represent the

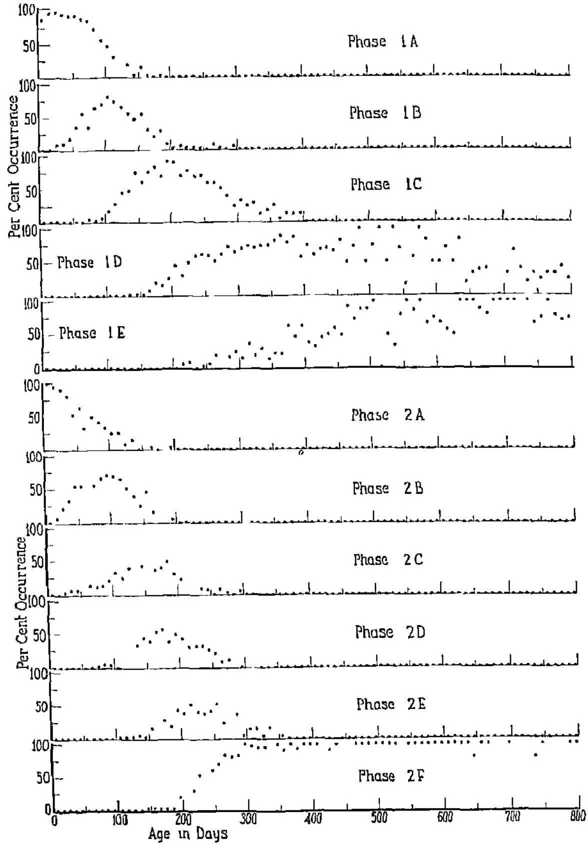

FIGURE 2

CURVE SHOWING ON A CHRONOLOGICAL SCALE THE PERCENTAGE DISTRIBUTION OF EACH PHASE AS MANIFESTED BY THE GROUP

average number of times each phase was given a plus rating over a 10-day interval. Two of these children, Peter and Charles Dalton, were identical twin boys, and the other two were unrelated girls. Patricia Shelley and Jane Woods had not achieved complete maturity in this activity at the time this report was prepared, and the curves representing Phases 1*D* and 1*E* do not in these cases show a stable trend.

TABLE 1

NUMBER OF OBSERVATIONS DURING EACH 10-DAY INTERVAL

Age interval in days	F	Age interval in days	F	Age interval in days	F	Age interval in days	F
1- 10	105	251-260	30	501-510	4	751-760	4
11- 20	31	261-270	25	511-520	3	761-770	3
21- 30	50	271-280	31	521-530	6	771-780	9
31- 40	41	281-290	30	531-540	3	781-790	7
41- 50	42	291-300	20	541-550	10	791-800	8
51- 60	54	301-310	33	551-560	6	801-810	5
61- 70	43	311-320	19	561-570	7	811-820	3
71- 80	43	321-330	21	571-580	3	821-830	4
81- 90	44	331-340	23	581-590	6	831-840	4
91-100	48	341-350	21	591-600	4	841-850	2
101-110	45	351-360	22	601-610	6		
111-120	40	361-370	18	611-620	7		
121-130	40	371-380	14	621-630	4		
131-140	52	381-390	15	631-640	6		
141-150	32	391-400	14	641-650	10		
151-160	44	401-410	16	651-660	6		
161-170	38	411-420	18	661-670	8		
171-180	35	421-430	13	671-680	5		
181-190	37	431-440	10	681-690	7		
191-200	35	441-450	15	691-700	2		
201-210	31	451-460	6	701-710	3		
211-220	33	461-470	12	711-720	3		
221-230	35	471-480	11	72-730	5		
231-240	32	481-490	8	731-740	5		
241-250	31	491-500	8	741-750	3		

The variability of the group as to the onset of any particular phase of development is shown in the series of curves in Figure 5. Phases 1*A* and 2*A* are present at birth and their earliest manifestation cannot therefore be determined. The curves in the left column of Figure 5 indicate the modal distribution of the group as to the emergence of each phase in the rising movement, which has been designated as the rising aspect of the behavior. The curves in the right column show the onset of developmental phases in the resistance to the force of gravity pulling the infant forward. It is noted that Phases 1*D* and 1*E* have bi-modal distributions. These bi-modal distributions are apparently due in a large measure to the criteria employed in making the ratings. The ogive curves indicate the total percentage of children who had, at any given age, achieved a particular phase. From these curves it can be seen that by the end of the second month most of the babies were exhibiting head and neck control during the rising movement, and by four and

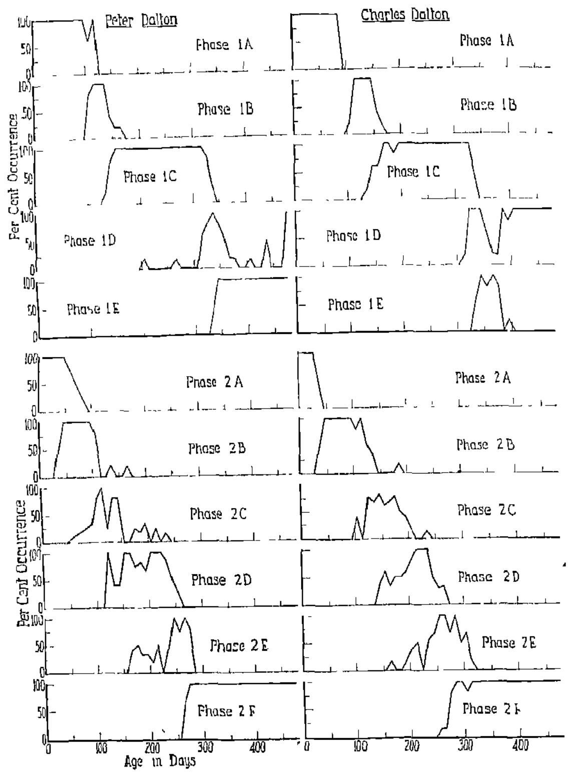

FIGURE 3

CHRONOLOGICAL PERIODS WHEN EACH PHASE IS THE CHARACTERISTIC MODE OF BEHAVIOR MANIFESTED BY IDENTICAL TWIN BOYS

one-half months most of them were beginning to exercise some effort in pulling against the force of gravity. The modal age for the assumption of an independent sitting position was approximately seven months. Toward the end of the fourth month marked resistance to the fall forward is manifested. The age at which most of them first show sufficient equilibratory control to sit in a leaning position, supporting themselves on the upper extremities, is 6½ months, and it is about 1½ months later when most of the infants achieve sufficient equilibrium to maintain an erect sitting position while using their arms for independent activities.

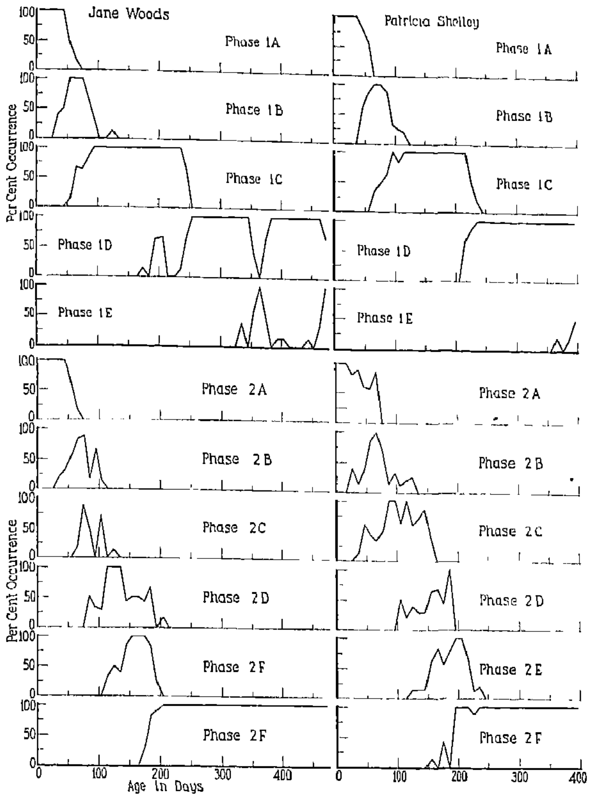

TABLE 4

CHRONOLOGICAL PERIODS WHEN EACH PHASE IS THE CHARACTERISTIC MODE OF BEHAVIOR MANIFESTED BY TWO UNRELATED GIRLS

Figure 6 shows for the group the modal age for the appearance of four phases in the rising aspect of the behavior, and the onset of each phase for the four children studied longitudinally. Figure 7 shows similar plots for five phases differentiating development in the resistive aspect of the behavior. These plots represent to some extent the adequacy of the criteria employed in differentiating the phases of development. If each phase is considered as a unit of development, it will be observed from the distribution of the dots in Figure 7 that the time involved in the maturation of Phase 2*A* is

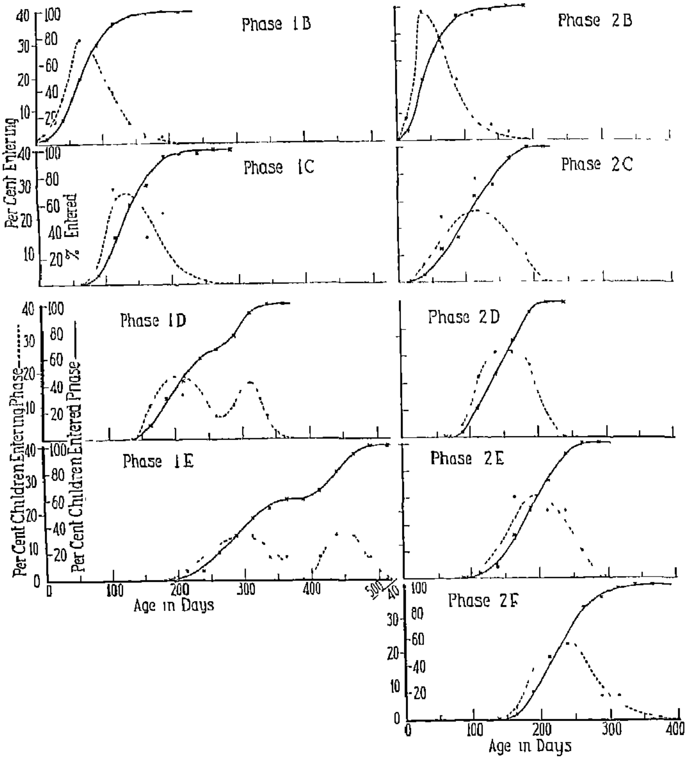

FIGURE 5

THE DOTTED-LINE CURVES INDICATE THE PERCENTAGE OF INFANTS AT EACH AGE INTERVAL WHO SHOWED THE EMERGENCE OF A PHASE DURING THAT TIME

The ogives show the total percentage of infants in whom the phase had been manifested at any given age.

practically equivalent to the time consumed in the maturation of Phases *2B*, *2C*, *2D*, *2E* and *2F*, whereas the time involved in the development of each phase of the rising aspect of the behavior shows considerable variation. These differences support the view that phases were more adequately selected for the resistive than for the rising aspect of the activity. In the resistive situation, the infant's behavior is elicited without appreciable outside interference, whereas in the first three phases of the rising situation the experimenter takes

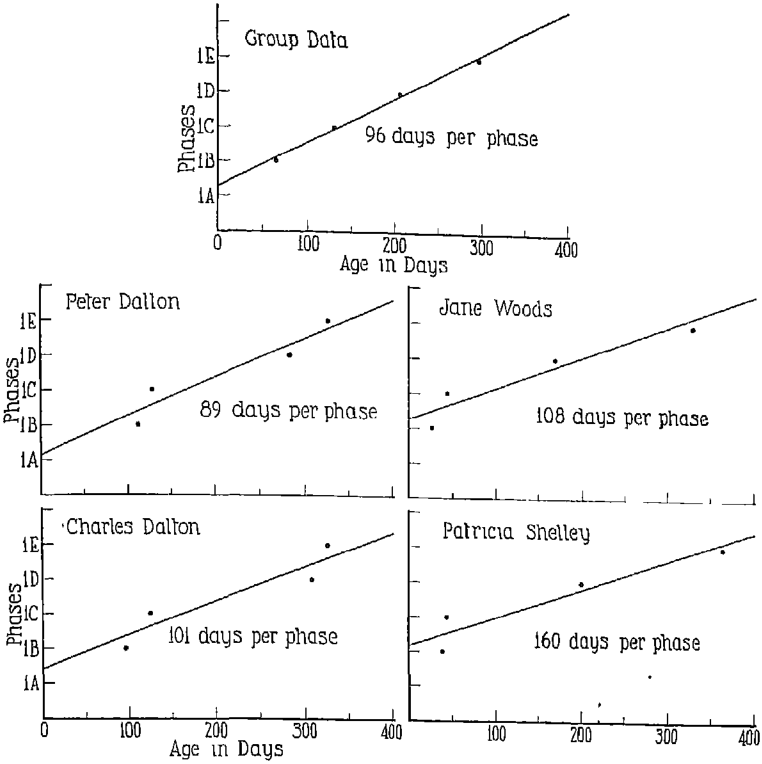

FIGURE 6

THE ONSET OF EACH PHASE AS SHOWN BY THE FOUR INDIVIDUAL INFANTS AND THE MODAL AGE OF THE GROUP AS TO THE EMERGENCE OF EACH PHASE OF THE RISING ASPECT OF THE BEHAVIOR PLOTTED AGAINST CHRONOLOGICAL AGE**

an active part in the movement, and the amount of effort exercised by the baby is determined not only by his own neuromuscular development but also by the amount of assistance or aid he receives from the examiner. Obviously, these are factors which cannot in this particular situation be precisely controlled. It has already been pointed out that the criteria for differentiating $1D$ and $1E$ are not as reflective of the developmental process as is desirable. Variations in the slopes (Figures 6 and 7) for individual children reflect indi-

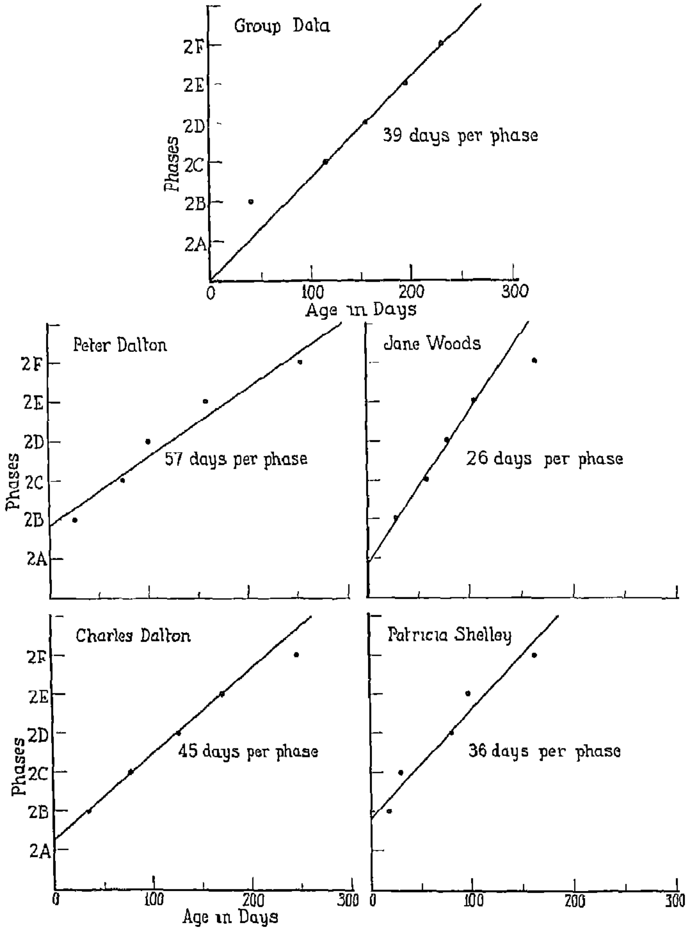

FIGURE 7

THE ONSET OF EACH PHASE AS SHOWN BY THE FOUR INDIVIDUAL INFANTS AND THE MODAL AGE OF THE GROUP AS TO THE EMERGENCE OF EACH PHASE OF THE RESISTIVE ASPECT OF THE BEHAVIOR PLOTTED AGAINST CHRONOLOGICAL AGE**

**Assuming the phases to be linearly distributed, the speed of progression from any phase to its succeeding phase may be simply expressed in days per phase, i e, the reciprocal slope of the data when the interval between any two phases represents a constant increase in behavior development

vidual differences in rates of growth within the limits of experimental error.

D. Interpretative Analysis

The assertion that enormous change in the neuro-muscular activities of the growing infant takes place during the first year of life needs no argument. A correlative statement that such behavioral development reflects cardinal change in the organization of the central nervous system would also meet with no serious objection, but the particulars of such structural-functional relationships remain a problem for future determination. On the other hand the mere chronological allocation of qualities in behavior activities which signify neuro-structural development is justifiable since such qualitative analysis constitutes a framework within which details may subsequently be elaborated.

The appraisal of behavior changes in neuro-muscular activities which consummate in the assumption of an independent sitting posture presents a problem of analysis somewhat different from that of other behavior patterns previously analyzed. Most behavior patterns developing during the first year of life are activities of phylogenetic origin. In ontogenetic development a primitive reflex pattern, controlled at a segmental level, usually characterizes the newborn phase. This feature is exemplified in the suspension grasp, swimming, prone, and erect progressive movements. In contrast, there is no definite reflex sitting posture in the behavior repertoire of the newborn infant. That the reflex movements of swimming and progression are common to many species and the absence among human infants of a reflex phase in the development of a sitting position provokes the hypothesis that the sitting posture, particularly sitting on the ischii, is an achievement of recent phyletic origin. Indeed, it is so recent that its organization at a reflex or segmental level is not recognized.[1] In any event the primary objective of the series of investigations of which this one is a part is to determine those qualities in each behavior pattern which reflect grossly the level of neural activation, specifically, whether they are of segmental or suprasegmental control. Since in the assumption of a sitting posture there is no distinct behavior pattern or reflex which characterizes segmental functioning, the onset of cortical functioning must be detected on its

[1]Infant chimpanzees appear to sit on the ischii with the lower extremities extended in front of them more frequently than do adult chimpanzees

own account without the aid of contrast or transition effects in behavior as the control shifts from a segmental to a suprasegmental level.

However, in the light of present knowledge, it seems reasonably certain that the cerebral cortex is not functioning appreciably at the time of birth. This assumption is supported by Tilney's (10) histological studies of the developing cortex in the human foetus and the newborn infant and also by the findings of Conel (1) who used various staining methods in his analysis of the newborn brain Certainly the passive attitude of the newborn baby reveals no distinctly voluntary or deliberate qualities. It is, therefore, within reason to infer that the movements and postures characteristic of Phases 1*A* and 2*A* are controlled at an infracortical level. However, the part of the motor cortex, viz., the middle one-third of the posterior wall of the anterior central gyrus, which controls movements of the upper trunk and shoulder girdle, is, according to Conel's (2) criteria, in a more advanced state of development at the time of birth than any other part of the cortex. It is in these regions that the first distinct qualitative changes are observed in the motor developments of the young infant.

Tilney contends that the first evidence of neo-cortical differentiation occurs in the parietal portion of the brain which has to do with the sensory components implicated in "body sense." Likewise, de Crinis (3), using the extension of dendrites as a criteria of structural maturation, found that earliest signs of morphological maturation occurred in the area governing muscle sense and in the sensory projection areas. Logically, it seems reasonable that the part of the brain which is concerned with the position of the body, or members of the body, and the movements of muscles should constitute the foundation of deliberate actions. Tilney believed that body sense took precedence over other special senses in the neural expansion which called the neocortex into existence. De Crinis, too, believes that muscle sense and the sensory and motor fields of the cerebral cortex, form the foundation or the "cornerstones" of conscious action. In view of these assertions it would be reasonable to expect that the first manifestation of neuro-muscular control would be educed in the anti-gravitational mechanisms. It signifies the very rudiments of body sense, the early adjustment to body displacement in space. The early changes in neuro-muscular behavior lend support to this supposition. As indicated by Phase 1*B* the earliest neuro-

muscular development is expressed by the orthotonic control of cervical muscles which enable the infant to hold the head in plane with the body axis while being pulled against the force of gravity. The inception of cortical influence over the movements involved in these two positions, viz., (*a*) resistance to, and (*b*) moving the body against gravitational forces, is definitely indicated during Phases 1*C* and 2*D*. Cortical participation is, of course, clearly evident during Phases 1*D* and 2*E*. After a neuro-muscular function has achieved cortical dominance, as indicated by the deliberate or voluntary qualities of the behavior, further development is expressed in the gradual elimination of excessive and incoördinate movements and the employment of a series of smoothly integrated movements in the consummation of a behavior. These are changes which occur primarily during Phases 1*E* and 2*F*.

Although this analysis covers the period from birth until the child is able voluntarily to assume and maintain a sitting posture, it does not in fact complete the story of development in this activity. As stated above, the assumption of a sitting posture is seemingly of recent phyletic origin. In any event, during ontogeny complete control over the activity is not achieved until the child can integrate the necessary movements involved in getting from an erect to a sitting position as well as from a supine to a sitting position. The ability to lower the body from an erect to a sitting position is, of course, achieved later. Observations on this aspect of the development will be discussed in a subsequent paper concerning ontogenetic development in the assumption of an erect posture.

E. Summary

Behavior changes characteristic of the human infant in the achievement of an independent sitting position have been analyzed so as to identify those features which reflect advancing organization of neural structures governing anti-gravity muscles. The analysis of these various phases is drawn from 1,717 observations of 82 infants ranging in age from birth to 800 days. In addition, longitudinal (daily) observations were made on four individual infants.

Five significant phases during the rising, and six during the resistive aspects of the behavior, have been described. Group and individual curves show the developmental trend of each phase. Modal distributions indicate the age periods when each phase is the characteristic manner of behavior.

Postural adjustments characteristic of the behavior of the newborn infant are seemingly controlled at a segmental level. Subsequent changes in reactions during the rising and the resistive situations indicate the onset of cortical participation in the behavior pattern. The first evidence of supra-segmental involvement is noted in the cervical region of the vertebral axis. Cited histological studies of the cerebral cortex indicate that the earliest signs of structural maturation are evident in the motor area which governs movements in the neck, shoulders, and upper extremities.

Unlike activities previously reported, there is no definite reflex sitting posture comparable to the subcortical swimming, crawling, and stepping movements of the newborn infant. This difference has led to the supposition that this behavior pattern is of recent phyletic origin and, therefore, was never organized at a segmental level.

Advancement in cortical control over the anti-gravity mechanisms manifests a cephalo-caudal trend. Complete development of the ability to assume and maintain a sitting position is not achieved until the child can get into a sitting from an erect, as well as from a supine, position. Development of this latter aspect of the behavior will be reported in connection with a report on the assumption of an erect posture.

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Normal Child Development Study
Department of Pediatrics
Columbia University
New York City

The Journal of Genetic Psychology, 1941, **59**, 177-188.

PATTERNS OF BEHAVIOR OF YOUNG CHILDREN AS REVEALED BY A FACTOR ANALYSIS OF TRAIT "CLUSTERS"*[1]

Institute of Child Welfare, University of Minnesota

KATHARINE M. MAURER

A. PURPOSE

As one means of throwing light on the patterning of behavior in young children, a list of descriptive adjectives was presented to 50 qualified raters, each of whom was asked to check those which seemed most applicable to a particular child known to the rater. The data were then subjected to a factor analysis in order to see whether psychologically reasonable groupings of behavior traits would emerge. A tentative interpretation of results has been made, as well as a further attempt to evaluate the technique used as an approach to the description of personality traits in young children.

B. PROCEDURE

1. *Criteria for the Selection of the Adjectives*

During a period of several months a list of approximately 600 adjectives descriptive of preschool children was compiled. An attempt was made to use Roget's *Thesaurus*, but this was not satisfactory as many of the words found there were obsolete. A better method was jotting down words while reading and conversing with friends, and then finding synonyms by the use of Webster's *New International Dictionary*.

The criteria used for the selection of the words were as follows:

1. All words were adjectives, descriptive of persisting or habitual rather than temporary modes of reaction.
2. No words containing moral implications, such as *bad, dutiful* etc., were included.
3. The words were those commonly used by people of the raters' level of education. Psychological terms, such as *introverted, subjective*, etc., were avoided.

*Received in the Editorial Office on May 23, 1940.

[1]Manuscript on file in the University of Minnesota Library.

4. The words were equally applicable to children between the ages of four and six years, and to older children and adults, in order that age-group comparisons might be possible if further study should be indicated by the results.

5. Finally, the words chosen were those for which satisfactory synonyms could be found.

The last two criteria proved to be the most limiting. Many words commonly used to describe adults were ludicrous when applied to children. Synonyms, on inspection, appeared almost always to provide a slightly different meaning. For this reason List II, made up of synonyms of List I, has only a partial resemblance to List I and gives, therefore, only a very crude estimate of the rater's consistency.

Reduction to about 200 words having been accomplished by the use of the above criteria, the remaining words were checked against List I of Allport's (1) psycholexical study of trait-names. A further reduction was made by eliminating all words which did not appear on Allport's List I, the criteria for which resembled those used for the first selection of words for this study. After this was done there still remained twice as many words as could be used effectively. I believed that a list of more than 50 words presented at one time might not receive the serious consideration which it was desirable to obtain, and that fatigue and boredom might enter in if a longer list were presented to the raters. The lists were finally reduced to 50 adjectives each by having a group of college students check the words which they most commonly used. Lists I and II were then mimeographed together with instructions to the raters.

List I

Grave	High-strung	Gay	Earnest
Frank	Careful	Deceitful	Calm
Active	Lawless	Listless	Heedless
Sociable	Keen	Aloof	Compliant
Cheerful	Plucky	Forward	Sluggish
Cautious	Silent	Sullen	Unobliging
Curious	Resourceful	Confiding	Talkative
Responsive	Domineering	Indifferent	Imitative
Impetuous	Independent	Insensitive	Submissive
Persistent	Sad	Meditative	Happy
Obstinate	Direct	Changeable	Quiet
Timid	Noisy	Amenable	Wavering
	Enthusiastic	Uninterested	

List II

Sober	Tense	Merry	Serious
Candid	Painstaking	Sly	Placid
Lively	Unruly	Languid	Careless
Friendly	Alert	Unsociable	Obedient
Good-natured	Brave	Bold	Slow
Wary	Taciturn	Sulky	Unaccommodating
Inquiring	Ingenious	Trustful	Garrulous
Socially sensitive	Dominating	Apathetic	Unoriginal
Impulsive	Self-reliant	Unresponsive	Docile
Persevering	Unhappy	Reflective	Joyous
Stubborn	Straightforward	Unpredictable	Inconspicuous
Shy	Boisterous	Reasonable	Vascillating
	Zestful	Bored	

2. *The Raters*

The raters were 50 women between the ages of 20 and 45. All of them had completed at least four years of college work or its equivalent. They were nursery school teachers, kindergarten teachers, graduate students in the Institute of Child Welfare and in the departments of Psychology and Education of the University of Minnesota, nurses who had received special training in the care of young children, and a few mothers of preschool children who had the required amount of education. All were personal acquaintances and in my judgment well qualified to rate children between the ages of four and six years.

3. *Directions to the Raters*

Before presenting List I, each prospective rater was asked if she knew a child of the required age range well enough to check a list of words describing him. When the answer was in the affirmative, List I was presented after a few words of explanation of the problem. The raters seemed to be very much interested and to take the rating seriously. It took from 10 to 20 minutes for each rater to read the directions and to check the list. The lists were planned with this approximate time limit in mind. The raters were told that they need not name the child, since it was supposed that the ratings would be more valid if this assurance were given them. However, a number of them insisted upon writing the child's name on the sheet. They were cautioned orally as well as in the written instructions to remember the child rated. The name of the rater and the date of checking the list were written in pencil on the back of each sheet, in order to pair the two lists and to secure the second

ratings in exactly one week's time. Ten additional raters were approached with the first list, in order to allow for such accidents as forgetting the child (two did this) and inability to reach the rater again.

Some of the raters appeared to be reluctant to check the second list. No questions regarding the words on List II were answered until the checking had been completed. As will be shown in the results, fewer words were checked on List II than on List I.

4. *Multiple Factor Analysis of List I*

The 50 words on List I were coded, and the frequencies punched on Hollerith cards and tabulated. The percentages for each two combinations of words were entered in four-fold tables on mimeographed sheets and tetrachoric coefficients were found for each of the four combinations by the use of Thurstone's computing diagrams (2). When less than 6 per cent or more than 94 per cent of the total number of words checked fell in one pair of cells, the tetrachoric coefficients could not be read from the diagrams. An attempt to fill them in, using Thurstone's and Kelly's long methods, did not yield consistent results. Thurstone's (2, p. 56) suggestion, to discard such combinations because of their extreme variability, was finally adopted.

A factor analysis, using Thurstone's centroid method (4), was then made of the remaining 26 words on List I, which were as follows:

Grave
Frank
Active
Sociable
Cheerful
Cautious
Curious
Responsive
Persistent
Obstinate
High-strung
Careful
Keen
Plucky
Resourceful
Domineering
Independent
Direct
Noisy
Enthusiastic
Forward
Meditative
Amenable
Earnest
Talkative
Happy

C. Results

1. *The Consistency of the Raters*

Since only about one-fourth of the words presented to the raters on Lists I and II combined were checked, it appears that lists of

50 words each are sufficient to permit raters to check most of the adjectives they will use in describing the social behavior of a child of four or five years of age. Of the total 1,315 words checked out of a possible 5,000, 750 words were on List I and 565 were on List II. Several explanations may be made for the greater frequency of checking the first list presented: that in spite of the attempt to distribute the best words evenly between the two lists, more of those which the raters accepted as serving their purpose appeared on List I, that the reluctance to check the second list noted by the investigator indicated an inhibition on the part of the raters when presented with the second list, or that they had lost interest in the problem. The average number of words checked per rater for the two lists combined was 26.3, an average of 15 for List I and 11.3 for List II.

The total number of words checked in agreement, that is, word and synonym both checked, was 836 or 418 pairs of words. This is about 64 per cent of the total number of words checked. The total number of words checked in disagreement (on one list only), was 479, 332 on List I and 147 on List II, 36 per cent of the total number of words checked.

The total agreement, however, includes the non-checked as well as the checked pairs of synonyms, since directions to the raters were to consider each word separately with reference to the child rated. The total agreement for checked and non-checked words was 4,040, 2,020 pairs of synonyms, 81 per cent of the total number of words presented.

The least consistent rater showed 62 per cent of agreement, and the most consistent rater showed 94 per cent of agreement.

When the shortened list on which the factor analysis was made and the synonyms on List II are examined, it appears that 80 per cent of the total number of words checked were retained. The percentages of agreement do not differ greatly from those obtained from the total lists. There were 1,058 words checked of the 2,600 words which might have been checked on the two shortened lists combined, 603 on List I and 455 on List II. Checked agreement was 68 per cent of the total number of words checked. The total agreement for checked and non-checked words was 74 per cent of the total number of words included on these lists.

When each word is examined for percentage of agreement, checked and non-checked, it appears: (*a*) that the poorer synonyms, such as

garrulous for *talkative,* and *zestful* for *enthusiastic,* account for a large part of the disagreement and (*b*) that some words, notably the less favorable ones, such as *sly* and *sulky,* have not been checked for this group at all, or very infrequently. Infrequent checking of undesirable traits is at least partly due to the fact that the raters chose the children to be rated themselves, and probably from their own social group, so that the children rated were highly selected with reference to social behavior. Ratings on children in some other social setting might make use of the less desirable words more frequently. Another explanation of the infrequency of checking some of the words might be that they were not applicable to young children. However, a great effort was made to include only those words which do apply.

2. *Factors*

Three factors were found to account for the intercorrelations with

TABLE 1
FACTOR LOADINGS OF THE 26 ADJECTIVES FOR EACH OF THE FIRST THREE FACTORS

Variables	I	II	III	h^2
Grave	—.66	+.45	+.61	1 0102
Frank	+.52	+.34	+.32	.4884
Active	+ 55	—.28	+.50	.6309
Sociable	+.78	+.28	+.34	.8024
Cheerful	+.80	+.39	+ 48	1.0225
Cautious	—.32	+.62	+.48	.7172
Curious	+.63	+.10	+.02	.4073
Responsive	+.64	+.61	+.28	.8601
Persistent	+.55	—.05	+.53	.5859
Obstinate	+.20	—.48	+.20	.3104
High-strung	+.20	—.42	+.42	.3928
Careful	—.32	+.58	+.12	.4532
Keen	+.68	+.54	+.41	.9221
Plucky	+.28	—.42	+.14	.2744
Resourceful	+ 60	+.52	+.33	.7393
Domineering	+.36	—.48	+.56	.6736
Independent	+.20	—.41	+.22	.2565
Direct	+.48	+.55	+.40	.6929
Noisy	+.24	—.60	+.16	.4432
Enthusiastic	+.81	+.20	+.09	.7042
Forward	+.34	—.42	+.43	4769
Meditative	— 48	+.40	+.34	.5060
Amenable	+ 32	+.37	—.01	.2394
Earnest	+.20	—.71	—.17	.5730
Talkative	+.64	— 38	+.28	.6324
Happy	+.70	+.17	—.52	.7893

residuals small enough to be ignored (mean residual .049). The loadings for the three factors are shown in Table 1. No attempt has been made to name the factors themselves due to their arbitrary nature, but the clusters which emerged will be discussed in some detail.

3. *Clusters*

The clusters are presented graphically in Figure 1, after applying the correction for uniqueness proposed by Thurstone (4, p. 118) for three-dimensional problems. Three clusters are discovered, two of which show a tendency to break up into sub-clusters. The first cluster, starting with those words plotted in the lower left quadrant

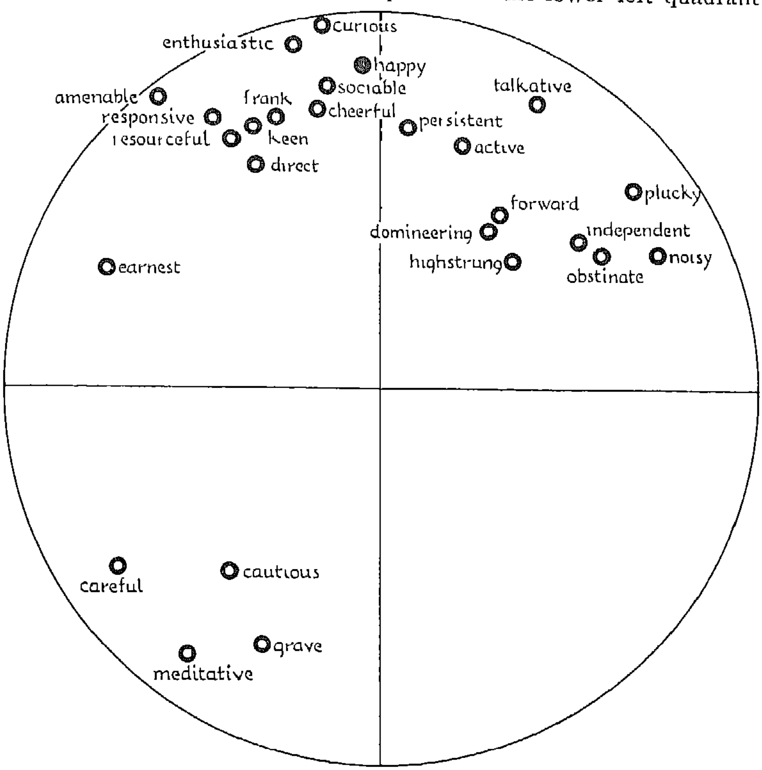

FIGURE 1
"Happy" is on the other side of the sphere but still within the cluster.

of the sphere, is made up of four words only. They are: *grave, meditative, cautious,* and *careful.* This is by far the smallest cluster, and reveals the opposite tendency from that reported by Thurstone (5), that is, these traits, which may be considered undesirable from a purely social point of view, are found in smaller numbers per cluster than those traits considered more desirable. This is probably due to the raters' selection of children to rate, and to the reluctance of people in general to say unfavorable things of a young child. The word *earnest* stands alone, and it is possible that if words similar to it are included when the study is repeated, a new cluster or sub-cluster, may be formed. The second cluster, in the upper left quadrant of the sphere, is made up of the following words: *Amenable, responsive, resourceful, direct, keen, frank, enthusiastic, curious, sociable, cheerful,* and *happy.* This cluster includes most of the traits on the list which are recognized as being socially desirable, that is, leading to successful contacts, and to acceptance by social groups. With repeated experimentation this cluster may break up into two, or perhaps more, distinct patterns. A third cluster, more loosely grouped but distinct from the others, is shown in the upper right quadrant of the sphere. It consists of the following words: *persistent, active, talkative, forward, domineering, high-strung, obstinate, noisy, independent,* and *plucky.* These are the words that one might use to describe a leader in a social group or a trouble maker. They are not the words associated with passive or conforming social behavior. That no words at all fall into the lower right quadrant seems to be due to the fact already mentioned: that the less desirable traits are not checked for these children. One can only speculate as to what clusters might have appeared if a less select group had been rated.

Only two other attempts (3, 5) have been made to apply factor analysis techniques to check-lists of personality traits as far as I know, although check-lists are used rather frequently for practical purposes in nursery schools and clinics. Unfortunately, neither of these studies has been reported with enough completeness to make detailed comparisons with the present investigation possible. In both, a very small number of factors has accounted for the intercorrelations, the clusters have appeared to be psychologically plausible, and the traits found within clusters have had suggestive similarities to the traits clustered in this study. No data has been presented by which the interrelationships between clusters could be compared.

Applications of factor methods to several rating scales of personality, using high school and college students as subjects, have demonstrated enough consistency with each other to make further study worth while in an attempt to establish useful categories on an empirical basis.[2]

Factor analysis has been applied to one study of the ratings on preschool children. Williams (6) revised Berne's *Social Behavior Scale* and made a factor analysis of the average of three ratings by nursery school teachers on 30 traits of social behavior. The children rated were 53 three-year-olds attending the Iowa State Research Station schools, for whom the same selective factors as were operative in this study may be assumed. Two factors were revealed by the analysis which Williams has described as related to (*a*) an approach-withdrawal tendency and (*b*) an ascendance-submission tendency. The factor loadings for each trait have been corrected for uniqueness and represented graphically in the same manner as the factor loadings for each trait of the present investigation. There is striking similarity between the kind of traits found in each cluster and also in the relationship between the clusters of the Williams' study and this one. Especially interesting is the fact that the Williams study, also, has no words checked in the quadrant opposite to that in which the highly desirable traits are found.

D. Further Study

The next step will be to improve the lists of traits used, keeping only those for which raters are consistent and obtaining as large a sampling as possible of social behavior traits. It may prove useful to break up the lists into several sub-lists, concentrating the attention of the raters on one phase of social behavior at a time. However, there may be danger of distorting the picture by presenting one aspect alone. If the favorable and unfavorable traits are presented separately, there may be more frequent checking of the unfavorable traits. These revised lists will be used with various groups as subjects and with various raters. Different age-groups will be studied to trace developmental trends; comparisons of various cultural and socio-economic groups may throw some light on the environmental

[2]A critical review and bibliography on the application of factor analysis techniques to the determination of clusters of personality traits is now in preparation and will be published in the near future.

factors involved; and groups which have already been selected by society because of inability to adjust to the accepted social mores, such as delinquent, psychotic, and neurotic groups, can be compared with groups which have met social requirements successfully. Comparisons of the ratings of teachers, parents, and mental hygienists for a given group of individuals may also prove enlightening. After categories of traits have been sufficiently tried out, a longitudinal study can be set up for the purpose of investigating the relative permanence of, and the shifts occurring in, the clusters for individuals and for groups.

E. Interpretations and Conclusions

An interpretation of the findings of this preliminary study must be considered tentative but may at least be mentioned as a possible explanation of trends discovered, and as an hypothesis upon which to base further investigation. The patterns as illustrated graphically in Figure 1 seem to arrange themselves in a graded series with the center of the sphere as an axis. Those traits which are grouped in the upper half of the sphere have to do with the approach tendency which is commonly associated with individuals well adjusted to the social group of which they are members. The traits in the upper right quadrant differ from those in the upper left quadrant in the matter of conformance to the accepted standards. Those at the left represent increasing degrees of conformance as well as adjusted behavior; those at the right represent increasing degrees of non-conformance as well as adjusted behavior. As the dividing line between the upper and lower halves of the sphere is approached going clockwise, there is less adjustment and more non-conforming behavior. Across the line in the lower right quadrant the traits are still those with a high degree of non-conformance but with increasingly maladjusted behavior. These are traits of a positive asocial nature such as one would expect to find in a delinquent group. At the bottom of the lower half of the sphere one would expect to find traits of extreme maladjustment which are associated with psychotic and neurotic individuals. In the lower left quadrant are varying degrees of the withdrawal type of maladjustment, a passive type of behavior in contrast to the active type of behavior in the lower right quadrant of the sphere. As the middle line is again approached, traits seem to take on a passive but social trend, decreasing in withdrawal behavior and approaching adjustment. This

is, it must be kept in mind, merely a suggested schema into which the traits in the clusters of this and the similar studies appear to fit.

The study of personality may be greatly advanced in two ways. First, there is need for the establishment of a universal terminology by which the investigations of various workers may be compared intelligently. The check list technique is especially valuable for this purpose since it is not limited to use with highly trained raters nor to any particular age group of subjects rated, and is also much less laborious to use than the other rating devices. The second way in which the study of personality may be advanced is by making longitudinal studies of personality traits, not in isolation, but in their relations to one another within an individual and in relation to a particular social setting. There are undoubtedly many patterns of personality which are both happy and socially valuable. Through longitudinal study it may be possible to find out something of the outcome of the various patterns of personality which appear in early childhood; that is, which patterns persist with little change, which are less stable, in which directions the shifts occur, and what the environmental concomitants of these shifts are. On this basis principles of education and mental hygiene may be established by which children may be guided away from social maladjustment toward happier and more effective lives.

F. Summary

Two lists of 50 adjectives each, describing young children, the second synonyms of the first, were checked one week apart by 50 raters for children between four and six years. A multiple factor analysis, using Thurstone's centroid method, was made of 26 of the adjectives from the first list. Three factors were found to account for the intercorrelations. The agreement between the raters, based on the frequency with which they checked or failed to check both words of a pair of synonyms was 81 per cent of the total number of words presented, and 74 per cent of the words used in the factor analysis. Three clusters, two of which may be subdivided, centered around reputations for (*a*) being extremely conforming (*b*) being sociable and somewhat conforming and (*c*) being non-conforming. These trends are also shown in other studies using similar techniques.

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Institute of Child Welfare
University of Minnesota
Minneapolis, Minnesota

The Journal of Genetic Psychology, 1941, 59, 189-206

A COMPARATIVE STUDY OF THE DIFFICULTY OF LEARNING THE MULTIPLICATION COMBINATIONS*

State Teachers College, Johnson City, Tennessee

LESTER R. WHEELER

What is the relative difficulty of learning the multiplication combinations? What factors influence these difficulties and what provision should be made for them in the instructional program? In answer to these questions we present a controlled learning experiment, compare the findings with other investigations, and attempt to evaluate the problem as a basis for pedagogical procedures. Various studies covering a wide range of grade levels, methods, and results are given in Table 1, and comments on each will be made as comparisons are studied.

Data for this experiment were gathered during 20 consecutive school days in October and November, 1939. A mimeographed test with the multiplication combinations presented in a chance order was given to 342 third grade children[1] in the public schools of Johnson City, Erwin and Carter County, Tennessee. The median *IQ* for this group was $101 \pm .82$, and the median mental age, 9 years, 0 months.

Immediately after this initial test *MULT-0*[2] was introduced. This is an educational game that teaches and drills 99[3] of the multiplication combinations through a free-play activity. With this teaching material it is possible to conduct controlled learning experiments with a large number of cases rather than with the necessarily limited number used by Holloway (21), Fowlkes (15), and Norem and Knight (28). The nature of the *MULT-0* material automatically establishes certain controls over the learning situation such as number of repetitions, type and quality of motivation, teaching method, vividness of presentation, typographical technicalities, and length of learning time. The correct combinations and answers

*Received in the Editorial Office on May 25, 1940.

[1]Third grade used in order to study initial learning of the multiplication facts.

[2]Augsburg Publishing Co., Morristown, Tennessee, 1938.

[3]0×0 is not included in *Mult-0*, therefore omitted in this study

TABLE 1
INVESTIGATIONS OF THE DIFFICULTY OF THE MULTIPLICATION COMBINATIONS

Date	Authors	Grade level	No. of cases	Methods of study	Results
1897	Philips	9th, adult	723	Teacher opinions. Number of errors.	Numbers 7, 8, 9 most difficult.
1912	Doring	ages 9-14, adult	1,053	Opinions. Number of errors.	Seven causes most difficulty. Lists hardest combinations. Gives difficulty of tables.
1914	Holloway	2, 3	200	Learning. Per cent of errors. Retention. Reaction time.	Omitted the zero combinations. Ranks 78 combinations up to 12 × 12.
1921	Smith	3-7 college	42	Reaction time.	Presents combinations in order of decreasing reaction time.
1924	Clapp	4-8	2,837	Number of errors.	Order of difficulty for each grade and all combined.
1925	Batson and Combellick	H. S., college	83	Reaction time by kymographic record.	Difficulty according to mental and physical reaction time, separately and combined.
1926	Rebarker	5-8	4,000	Per cent of errors.	Ranked according to grade and all grades combined.
1927	Fowlkes	3	31	Initial learning Per cent of errors. Controlled practice.	Ranked according to difficulty. Comparisons made with Clapp.
1928	Anspaugh and Phipps	6	1,011	Per cent of errors.	Ranked according to number of errors.
1928	Washburne and Vogel	2-8	845?	Per cent of errors. Based on individual instruction methods.	Gives hardest and easiest quartiles of the combinations.
1930	Norem and Knight	3	25	Initial learning. Number of responses Reaction time. Per cent of errors Retention Controlled practice.	Difficulty ranks based on practice, error and speed. Comparisons made with Clapp.
1930	Rock and Foran	3-8	?	Composite study of thirteen previous investigations.	Ranked according to mean difference between quartile placement.
1939	S. M. Washburne	4-8	3,800?	Attempt to repeat Clapp's study Per cent of errors.	Published data insufficient for analysis and comparisons. Claims results agree with Clapp.

are always before the children, minimizing the possibilities of establishing incorrect responses. Accuracy is checked and speed is regulated in an effort to control undesirable habits of computation. The game is simple and, even though motivated by a real spirit of play, attention is focused on the number combinations rather than on the process of the game. Interest in the game increases with use; the more combinations a child masters the more fun it is to play.[4] The procedure used in *MULT-0* was that outlined in the "directions for playing" accompanying the game. When *MULT-0* was introduced a brief explanation was given as to the nature of multiplication and how it differs from addition. The teachers then refrained from teaching by any method except *MULT-0*. No incentive other than the game itself was used for motivation, and no attempt was made to supervise or assist the teachers in any way except to administer tests and to give initial instruction as to the nature of multiplication and how to play the game. *MULT-0* was played 20 minutes a day for five consecutive school days, then the multiplication test was repeated. This procedure of playing and testing was repeated during four weeks, and progress from week to week studied.

Table 2 gives the testing results. The initial test shows that the children knew about nine combinations at the beginning of the experiment; the range is 0-75.[5] This increased to around 51 combinations on the final test, showing a gain of 42 combinations during the 20-day experiment, or an average of 2.2 new combinations learned each day. At this rate, children beginning third grade should learn the 100 combinations during a minimum period of 46 days, or nine or ten school weeks. There is a consistent increase in the first and third quartiles, and no marked change in the semi-interquartile range. The largest gain was made during the first five days of the experiment when 4.3 new combinations were learned a day. In other words the children learned three times as many combinations during the first week as during any one of the following weeks. It appears safe to conclude that this decrease in rate was not affected by the ability of the absent cases: first, the rate of learning remains fairly constant after the first week even though there continues a decrease in number of cases; second, there is no material

[4]For details of playing educational games *READ-0, ADD-0, MULT-0*, etc., see Goforth (16).

[5]Fowlkes reports the third grade children in his study knew 23 combinations in the initial test with a range of 0-66.

TABLE 2

THE RESULTS OF TESTING, SHOWING NUMBER OF MULTIPLICATION FACTS KNOWN AT EACH TESTING, THE GAIN MADE ON EACH TEST, THE TOTAL GAIN, AND THE GAIN PER DAY

	Test 1	2	3	4	5	Total gain Test 1 to 5
Number of cases	342	330	318	307	304	
Median	9.3±.899	30.7±1.111	38 1±1.262	44.4±1 229	51 6±1.191	42 3±2 109
Q-1	1 6	16 7	18.6	27.1	34 6	33.0
Q-3	28.2	49.1	54 6	61.6	67.7	39.5
Q	13 3	16.2	18.0	17.2	16 6	3.3
Gain		21.4	7.4	6 3	7 2	42.3
Gain per day		4.3	1.5	1.3	1.4	2.2

difference in the average ability of those who were absent (*IQ* 103) and the total group (*IQ* 101); and third, the correlation between *IQ* and rate of learning the combinations is very low, $r = .18 \pm .037$. The rapid rate of learning during the first week may be explained by a study of the relative difficulty of the combinations; over a third of the multiplication facts is made up of those containing *0* or *1*, and the following discussion explains that these combinations are the easiest to learn.

The combinations were ranked from easiest to most difficult on the basis of the number of children mastering each combination on each test. Correlations between the difficulty rankings on the five tests are:

Test 1 with Test 2	$r = 92 \pm .010$
Test 2 with Test 3	$r = 98 \pm .003$
Test 3 with Test 4	$r = .99 \pm .001$
Test 4 with Test 5	$r = .98 \pm .002$

These high correlations show a consistent and close relationship between the rankings; the results at almost any period during the experiment would have given reliable results. The final ranking, shown in Table 3, was obtained by averaging the ranks from Tests 2, 3, 4, and 5.

The easiest combination is 1×0, mastered by 83 per cent of the children, and the difficulty increases gradually to 7×9 which was learned by only three per cent. A study of the increment of difficulty existing between the combinations shows that the difference from one rank to the next is consistently small throughout the table, with an average step difference of .80. An analysis of this increment of difficulty is made by studying the average step difference according to quartiles:

Average step difference in first quartile (easiest)	.78
Average step difference in second quartile	.84
Average step difference in third quartile	1.15
Average step difference in fourth quartile (hardest)	.45
Average step difference in second and third quartiles	.99

Here we find less difference between the ranks of the hardest quarter, indicating a relatively small increment of difficulty exists among the most difficult combinations; the smaller the step the more similar the difficulty. The easiest quarter shows a larger increment, increasing still more in the second and third quartiles. This is contrary to the trend found by Washburne and Vogel who state that "the differences among the combinations are distinctly greater to-

TABLE 3

THE MULTIPLICATION COMBINATIONS RANKED FROM EASIEST TO MOST DIFFICULT

	Average rank	Average % of cases mastering each	Step difference in rank		Average rank	Average % of cases mastering each	Step difference in rank
1 × 0	1	83.75	—	4 × 4	51	40.00	2.50
0 × 1	2	76.25	7.50	5 × 5	52	39.25	.75
1 × 1	3	75.00	1.25	7 × 2	53	38.75	.50
7 × 0	4	74.25	.75	3 × 3	54	36.00	2.75
5 × 1	5	73.25	1.00	6 × 2	55	35.00	1.00
3 × 0	6	73.00	.25	3 × 6	56	32.75	2.25
9 × 0	7	72.50	.50	5 × 4	57	30.25	2.50
7 × 1	8	72.00	.50	4 × 5	58	30.00	.25
0 × 8	9	71.00	1.00	3 × 4	59	29.00	1.00
4 × 1	10	69.50	1.50	4 × 3	60	28.75	.25
6 × 0	11	69.25	.25	3 × 9	61	26.00	2.75
1 × 2	12	68.50	.75	3 × 8	62	25.75	.25
0 × 4	13	68.00	.50	6 × 6	63	25.50	.25
5 × 0	14.5	67.50	.50	9 × 9	64	25.00	.50
9 × 1	14.5	67.50	.00	6 × 3	65	22.75	2.25
0 × 5	16.5	67.25	.25	3 × 7	66	21.50	1.25
0 × 3	16.5	67.25	.00	8 × 5	67	21.00	.50
4 × 0	18	67.00	.25	6 × 4	68	20.25	.75
2 × 0	19	66.50	.50	7 × 3	69	20.00	.25
0 × 2	20	65.50	1.00	6 × 5	70	18.25	1.75
3 × 1	21	65.25	.25	4 × 6	71	15.50	2.75
1 × 6	22	64.75	.25	5 × 8	72	15.25	.25
1 × 3	23	64.50	.25	9 × 3	73	15.00	.25
2 × 2	24	64.25	.25	9 × 5	74	14.75	.25
6 × 1	25	64.00	.25	5 × 6	75	13.75	1.00
0 × 6	26	63.50	.50	8 × 3	76	13.25	.25
0 × 9	27	63.00	.50	7 × 4	77	12.75	.25
8 × 0	28	62.75	.25	7 × 5	78	12.50	.25
2 × 1	29	62.50	.25	9 × 8	79	12.00	.50
8 × 1	30	62.00	.50	5 × 9	80	11.75	.25
1 × 8	31	60.50	1.50	5 × 7	81.5	11.50	.25
1 × 5	32	60.00	.50	4 × 8	81.5	11.50	.00
2 × 4	33	59.25	.75	8 × 8	83	11.00	.50
2 × 5	34.5	58.25	1.00	4 × 7	84	10.50	.50
0 × 7	34.5	58.25	.00	8 × 4	85	10.00	.50
1 × 7	36	57.50	.75	4 × 9	86	9.50	.50
2 × 6	37.5	57.00	.50	9 × 4	87	9.25	.25
1 × 9	37.5	57.00	.00	8 × 9	88	9.00	.25
1 × 4	39	56.75	.25	7 × 7	89	8.75	.25
2 × 9	40	55.00	1.75	8 × 6	90	6.50	2.25
2 × 3	41	54.00	1.00	6 × 8	91	6.00	.50
2 × 8	42	52.25	1.75	8 × 7	92.5	5.00	1.00
9 × 2	43	49.75	2.50	6 × 7	92.5	5.00	.00
2 × 7	44	49.00	.75	7 × 8	94	4.25	.75
4 × 2	45	48.75	.25	9 × 7	95	4.00	.25
5 × 3	46	46.00	2.75	7 × 6	96	3.75	.25
5 × 2	47	45.50	.50	6 × 9	97	3.50	.25
3 × 2	48	45.25	.25	9 × 6	98	3.25	.25
8 × 2	49	42.75	2.50	7 × 9	99	3.00	.25
3 × 5	50	42.50	.25	Average			.80

ward the lower and upper extremes than in the middle" (43, p. 241). They also found that the order of difficulty in the middle 50 per cent was not consistent and considered it "pedagogically unimportant." Unfortunately these authors failed to publish data which would make their investigation comparable to other studies.

Our ranking is compared with other investigations in Table 4. Here is shown a substantial agreement with all studies except those of Rebarker (32), Clapp (11), and Anspaugh and Phipps (1). For some reason the latter does not agree with any other investigation and we are inclined toward the opinion that either the ranking of Anspaugh and Phipps is in error or else the results of the other studies are worthless. Perhaps this marked discrepancy explains why later investigators ignored the study. It was used in the composite rank compiled by Rock and Foran (35) even though the authors found a similar variation. Rock and Foran, by using the mean differences between quartile placements of the combinations, found a trend of agreement among the various investigations similar to that indicated by the correlations in Table 4.

TABLE 4

THE RELATIVE DIFFICULTY OF THE MULTIPLICATION COMBINATIONS AS FOUND IN THIS STUDY COMPARED WITH OTHER INVESTIGATIONS

Wheeler ranking correlated with:	$r =$	When zero combinations omitted, $r =$
1. Fowlkes	.81±.023	.85±.027
2. Smith	.84±.021	.84±.023
3. Holloway (45 combinations)	.93±.015	
4. Rebarker	.15±.068	.89±.016
5. Clapp	.11±.070	.92±.012
6. Norem and Knight	.84±.019	.98±.001
7. Anspaugh and Phipps	—.39±.060	—.35±.068
8. Batson and Combellick (mental and physical)	.89±.070	.82±0.26
9. Batson and Combellick (mental reaction-time)	.34±.061	

Breuckner (5), Buswell (10), and Ruch (36) have emphasized the fact that there appears considerable disagreement among the results of these studies. Explaining that the discrepancies are probably due to differences in the ways the various studies were conducted, these authors conclude, first, that learning difficulties are very different from final difficulties, and second, that none of the difficulty ranks is reliable for use as a basis of textbook construction. Actually there is much more agreement than disagreement among these inves-

tigations; the marked discrepancies in ranking disappear when the zero combinations are omitted in making comparisons. By this procedure the low correlations of Clapp and Rebarker are changed to high correlations, indicating that, with the exception of the zero difficulties, their rankings agree fairly well with the others. As the other investigations correlate fairly close with our ranking, we assume that the comparisons previously made between them and Clapp would be similarly affected by omitting the zero combinations: Norem and Knight correlated with Clapp, $r = .32$; Fowlkes with Clapp, $r = .42$. Since Washburne and Vogel report their ranking correlates .93 with Clapp and they place the zero combinations in the hardest quartile, we assume a similar situation holds true for their results. This analysis indicates a trend contrary to that suggested by Breuckner, Buswell, and Ruch; first, that initial learning difficulties are not necessarily different from difficulties found to persist after some years of instruction, and second, that there is sufficient agreement among investigators to warrant use of the lists for instructional procedures.

Turning to Table 1 we find that previous investigations include all ages beginning with Grade III through college, as well as a wide range in number of cases from 25 to several thousand. Summing up the objective methods used we find they include the results of initial learning, reaction time, per cent of errors, retention, and composite studies based on various combinations of two or more of these methods. While various teaching methods were found, they apparently affected the general comparison of the rankings in only one serious respect, that of the zero difficulties. It appears that the zero combinations are easily learned when they are taught with stress and practice similar to that put on the other combinations. In view of the high correlations between the various studies when the zero combinations are eliminated, we conclude that regardless of the methods of study, grade level of the children, or methods of teaching, certain combinations are more difficult to learn than others, and the combinations fall into a relative ranking according to the difficulty of learning. In reviewing the early studies of Doring (13), Philips (30) and others, it is interesting to note that, while "opinions" constituted the principal method of study, the results are in fair agreement with those of later investigations. A comparison of the difficulties studied by "tables" is shown in Table 5.

Why is one combination more or less difficult than another? Norem

TABLE 5

A STUDY OF THE DIFFICULTY OF THE MULTIPLICATION COMBINATIONS WHEN ARRANGED IN TABLES

Tables	Average difficulty	Range	Ranks of tables[+]				
			Wheeler	Doring	McMurray	Gildemeister	Rocke, Roeger, and Wolf
0's	15.2	1- 29	1	–	–	–	–
1's	19.9	1- 40	2	2	–	3	2
2's	37.7	12- 56	3	3	3	2	3
3's	50.1	6- 77	4	4	7	6	7
4's	57.0	10- 88	6	6	5	7	5
5's	53.2	5- 82	5	5	4	5	4
6's	63.6	11- 99	7	7	8	8	8
7's	68.0	4-100	10	10	10	10	10
8's	65.8	9- 95	8.5	9	6	9	6
9's	65.8	7-100	8.5	8	9	4	9

[+]Easiest is rank 1, hardest is rank 10

and Knight (28) suggest size of product, order of presentation, delicate interrelationships, interchange of multiples, and a series of unknowns. Washburne and Vogel (43) conclude that size of the numbers in a combination, the doubles, and the use of zero causes inherent easiness or hardness. The arrangement of the combinations in Table 6 shows there is a close relationship between the size of the product and relative difficulty ranking, $r = .92 \pm .016$. This is higher than the agreement found either by Norem and Knight ($r = .86 \pm .03$) or Clapp ($r = .61 \pm .07$), and suggests that our ranking more nearly approaches the size-of-product hypothesis than do those of other investigators. While the size of product may be used as a general index of difficulty, it is probably not a cause of difficulty but rather the logical result of the size of the numbers making up the combinations. The size of the numbers also agrees closely with difficulty, $r = .94 \pm .026$ and appears the better index of difficulty.[6] However, we do not agree all the way with Washburne and Vogel (43, p. 251) that "easiness of the multiplication combinations appears to be solely due to the smallness of the factors"; other factors affect inherent difficulty to varying degrees. The ease of learning is affected to some extent by the relation of reverse combinations, as shown in Table 6. A correlation of $.80 \pm .041$ is found between the combinations and their reverses; Clapp reports $.91 \pm .02$, and Norem and Knight $.76 \pm .04$. As we have already shown, it is mainly the placing of zero combinations that has caused marked discrepancies among various difficulty ranks. Those investigators who found the zero combinations in the hardest quartile of a ranking concluded accordingly that zero was a cause of inherent difficulty. Our ranking and comparisons point to the fact that when sufficient opportunity is given for experience and practice the zero combinations are the easiest of all combinations. Zero itself does not appear to be a cause of difficulty. We conclude with Ruch that "zero difficulties arise from neglect and disappear under controlled instruction" (36, p. 377).

Does the number of repetitions affect difficulty? In *MULT-0* the doubles combinations appear on the child's playing cards 4.5 times oftener than the zero combinations, and all other combinations appear three times oftener than the zeros, yet the zero combinations were learned easiest. Repetition alone does appear to assure ease of

[6]Size of product advocated by Norem and Knight, and Klapper. Size of numbers advocated by Brueckner, Washburne, and Clapp.

TABLE 6

THE MULTIPLICATION COMBINATIONS GROUPED ACCORDING TO THE SIZE OF THEIR FACTORS AND ACCORDING TO REVERSES

Combination	Difficulty rank	Quartile placement	Reverse	Difficulty rank	Quartile placement	Size of the product
1 × 0	1	1	0 × 1	2	1	0
2 × 0	19	1	0 × 2	20	1	0
3 × 0	6	1	0 × 3	16.5	1	0
4 × 0	18	1	0 × 4	13	1	0
(0) 5 × 0	14.5	1	0 × 5	16.5	1	0
6 × 0	11	1	0 × 6	26	2	0
7 × 0	4	1	0 × 7	34 5	2	0
8 × 0	28	2	0 × 8	9	1	0
9 × 0	7	1	0 × 9	27	2	0
Average	12.06			18.27		0
Range	1-29			2-35		0
2 × 1	29	2	1 × 2	12	1	2
3 × 1	21	1	1 × 3	23	1	3
4 × 1	10	1	1 × 4	39	2	4
(1) 5 × 1	5	1	1 × 5	32	1	6
6 × 1	25	1	1 × 6	22	1	6
7 × 1	8	1	1 × 7	36	2	7
8 × 1	30	2	1 × 8	31	2	8
9 × 1	14 5	1	1 × 9	37.5	2	9
Average	17.81			29.06		5 6
Range	5-30			12-40		2-10
3 × 2	48	2	2 × 3	41	2	6
4 × 2	45	2	2 × 4	33	2	8
5 × 2	47	2	2 × 5	34.5	2	10
(2) 6 × 2	55	3	2 × 6	37 5	2	12
7 × 2	53	3	2 × 7	44	2	14
8 × 2	49	2	2 × 8	42	2	16
9 × 2	43	2	2 × 9	40	2	18
Average	48 57			38 85		12
Range	43-56			33-45		6-20
4 × 3	60	3	3 × 4	59	3	12
5 × 3	46	2	3 × 5	50	2	15
(3) 6 × 3	65	3	3 × 6	56	3	18
7 × 3	69	3	3 × 7	66	3	21
8 × 3	76	4	3 × 8	62	3	24
9 × 3	73	3	3 × 9	61	3	27
Average	64.83			59.00		19.50
Range	46-77			50-67		12-28
5 × 4	57	3	4 × 5	58	3	20
6 × 4	68	3	4 × 6	71	3	24
(4) 7 × 4	77	4	4 × 7	84	4	28
8 × 4	85	4	4 × 8	81.5	4	32
9 × 4	87	4	4 × 9	86	4	36
Average	74 80			76.10		28 00
Range	57-88			58-66		20-37

TABLE 6 (*continued*)

Combination	Difficulty rank	Quartile placement	Reverse	Difficulty rank	Quartile placement	Size of the product
6 × 5	70	3	5 × 6	75	4	30
(5) 7 × 5	78	4	5 × 7	81.5	4	35
8 × 5	67	3	5 × 8	72	3	40
9 × 5	74	3	5 × 9	80	4	45
Average	72.25			77.13		37.50
Range	67-79			72-82		30-46
7 × 6	96	4	6 × 7	92.5	4	42
(6) 8 × 6	90	4	6 × 8	91	4	48
9 × 6	98	4	6 × 9	97	4	54
Average	94.5			93.5		48
Rank	96-99			92.5-98		42-55
(7) 8 × 7	92.5	4	7 × 8	94	4	56
9 × 7	95	4	7 × 9	99	4	63
Average	93.75			96.5		59.5
Range	92.5-96			94-100		56-64
(8) 9 × 8	79	4	8 × 9	88	4	72
		(Doubles)	1 × 1	3	1	1
			2 × 2	24	1	4
			3 × 3	54	3	9
			4 × 4	51	3	16
			5 × 5	52	3	25
			6 × 6	63	3	36
			7 × 7	89	4	49
			8 × 8	83	4	64
			9 × 9	64	3	81
			Average	53.67		
			Range	3-90		

mastery. A similar trend was found in a study of the addition combinations (45), and this conclusion agrees with Holloway (21), Clapp (11), and Washburne and Vogel (43).

While mental maturity and arithmetic readiness may determine when the combinations should be taught, these factors do not appear to materially influence the relative difficulty of learning the combinations; similar trends in relative difficulty persist through all grade levels, Grade III through college. Döring (12) and Washburne (42) point out that difficulty is affected by familiarity with the numbers that make up the combinations, thus the child learns the smaller combinations easiest. If this were so, then the zero combinations would be the most difficult; children have less experi-

ence with or use for zero than any other number. Griggs (17) and Tingley (40) suggest that the basis of our number system, calculating by tens, is unnatural and contributes materially to difficulty of learning. Norem and Knight have suggested that difficulty might arise in confusions due to several combinations having the same product; in our investigation we find no evidence to support this theory.

Batson and Combellick (2), ranking the combinations on the basis of mental and physical reaction time, found the range of relative mental difficulty of the combinations is not so great as the range of relative physical difficulty of writing results. Their findings suggest that the difficulties found by measuring the written responses to the combinations involves more physical than mental factors. By correlating their difficulty ranks with ours we find a correlation of .89±.070 when both mental and physical reaction time is used as a basis of ranking, but only .34±.061 with mental reaction time alone. Further experimentation on this problem is needed to determine the influence of visual, acoustic, and motor hindrances. We found reversals occuring frequently in writing the answers on the tests, indicating the influence of visual habits on the written response (46).

Contrary to the opinion of Ruch (36) and Klapper (23), third grade children make use of certain generalizations which simplify learning. At the beginning of the experiment when the nature of multiplication was discussed, a brief explanation was given of the generalizations governing multiplying by zero and 1. The use of these "rules" probably accounts for much of the progress made in learning these combinations. This ability to generalize undoubtedly accounts for the relation of difficulty between a combination and its reverse.

It is natural that considerable confusion in learning the multiplication facts will arise from a carry-over of the addition process. The tendency to add persisted in some cases throughout the experiment and constitutes a difficulty of considerable pedagogical significance. The relative difficulty is also materially affected by teaching additive counting, a crutch which aids learning the small combinations but hinders the rate of progress with the larger. Döring has suggested other factors that might influence difficulty: rhythm; perceptual patterns; relationships between the processes of addition, multiplication, and division; memory based on judgment; mental

set; and certain numbers rich in associations. He also suggests that factoring may influence difficulty; 7, the most difficult number in multiplication, is the largest number that cannot be factored in the manner of 9 or 6.

Several educational implications are suggested by the results of this investigation. If one assumes that the easiest combinations should be learned first, the combinations are grouped in a convenient teaching sequence in Table 6. By studying the quartile placement we find that in general the 0's, 1's and 2's make up the easiest quartiles and the 6's, 7's, 8's and 9's the hardest. The quartile placement of the doubles indicates where each should be considered in the teaching order, thus 1×1 and 2×2 should be taught along with the 0's and 1's. The size of the numbers in a combination is a fair index of relative difficulty.

A child learns the multiplication facts solely to facilitate computation, and the ease of computation depends entirely upon the degree of mastery in terms of correct automatic response. The aim is to teach for one hundred per cent automatization of the number facts. Present methods of presenting the combinations increase rather than decrease the learning difficulties; they are logical but not psychological in approach. By introducing each multiplication fact by means of a concrete situation explained by additive counting ($3 + 3 + 3 = 9$), the association of adding is emphasized and suggests a "crutch" which children readily employ (23, pp. 254-256). Associating the process of multiplication with addition also suggests counting-up the answer. It is too much to expect that a child, introduced to a combination through addition, will not use this method in computing an answer. In multiplication as well as in the other arithmetic processes some children develop an amazing skill in the use of "crutches." While this procedure makes learning the smaller combinations very easy and may speed up initial learning, it hinders development of the rapid automatic response which is so essential for satisfactory progress with the larger combinations, with subsequent arithmetic processes, and for practical use in life. It is questionable whether introducing multiplication by additive concepts is any improvement over teaching by "tables"; both serve as aids in initial learning which have to be torn down and replaced by memorization before rapid and quick responses are possible. The basic psychological principles of learning are the same for all subjects, yet, while the alphabet method of teaching

reading is condemned, the same educators advocate a similar inductive method of teaching arithmetic.

Children with the ability to use judgment in varying degrees discover and use certain generalizations to aid their memory. This, however, is very different from depending on "crutches" and is to be highly recommended and encouraged. Learning the number combinations should be considered as a task of memorization, and the psychological principles for economy in memorizing should be applied even during initial instruction. Memorizing the combinations without the encumbrances of counting-up or adding may be a slower process in learning the easier combinations, but in the end it will mean a useful and immediate command of all the combinations. The time to present concepts of adding in multiplication is after the facts have been memorized, never before. Instruction may be improved by observing the following suggestions:

1. The minimum time in which beginning third grade children can be expected to learn the multiplication combinations is nine or ten weeks. This will vary according to the ability of the group and with those individuals within the group who do not conform to the average in arithmetic experiences, training, ability, study habits, interests, etc.
2. Keep combinations to be learned constantly before the children, on blackboard or in some conspicuous place, until they are mastered, in the same manner the first grade teacher exposes the beginner to a reading environment.
3. Call special attention to the difficulties.
4. Point out simple generalizations, such as apply to the zero combinations, any number multiplied by 1, and the rule for the 5's.
5. Provide adequate opportunity for repeated uses for the combinations.
6. Provide well motivated drills under sufficient time limits to discourage use of crutches.
7. Time limits should probably vary for different children. Some children respond slower than others because of physical factors, skill in writing, vocalizing, etc.
8. Use consistently each school day all the combinations which are being learned.
9. Vary drill procedures to stimulate interest.
10. Supplement text and work-book materials with various illustrations and practical problems.

11. For the difficult combinations provide a longer learning time, greater amount of drill and experience, and more maintenance drill.

12. During initial learning avoid suggesting any "crutch" such as counting-up and additive counting.

13. Teach the concepts of additive counting only after the combinations have been memorized.

14. Teach reverses at the same time as the direct combinations and emphasize the generalizations which apply.

15. Avoid teaching the combinations in any consecutive order. If the easiest quartile is taught first (see Table 6), vary the order of presenting these combinations from day to day.

16. The combinations are mastered when the child can respond to the hundred facts in from 114 to 240 seconds (2).

17. Provide adequate maintenance drill after combinations have been learned. Norem and Knight found one practice a week sufficient for maintenance after mastery. This should be considered in view of the fact that they studied a superior group of children (*IQ* 121). Drill should be increased with decreasing ability.

18. A free-play activity in a highly motivated game such as *MULT-0* may be successfully used in teaching the multiplication combinations.

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State Teachers College
Johnson City, Tennessee

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A COMPARATIVE STUDY OF THE PERSONALITIES, INTERESTS, AND HOME BACKGROUNDS OF GIFTED CHILDREN OF SUPERIOR AND INFERIOR EDUCATIONAL ACHIEVEMENT*

Murray State Teachers College, Murray, Kentucky

W. D. LEWIS

Gifted children have been the subjects of numerous investigations during the past two decades, but the methods of selection used in most of these studies have been such that the groups have been composed, for the most part, of children who were making such rapid progress in their school work that their achievement had made their superiority almost self-evident. Thus, most of our information about gifted children pertains to those whose achievement is somewhat in accord with what might be expected in the light of their native ability. The writer is of the opinion that our information relative to superior children is deficient in that we know far too little about those who are designated as superior by standardized intelligence tests but who are not making effective use of their superior ability, and, as a result, often are never recognized as superior. The present study seeks to consider this deficiency in the data to some degree, and has as its major purpose the presentation of data pertaining to superior children who are achieving relatively little. They are compared with another group of gifted children selected because of their relatively great achievement.[1]

These two groups of superior children were selected from 4,529 children who constitute the upper 10 per cent in intelligence, as determined by the Kuhlmann-Anderson *Test*, of approximately 45,000 pupils drawn from an elementary school population in grades four to eight, inclusive. These children were found in 455 schools, 310 communities, and 36 states. The writer believes that the wide

*Received in the Editorial Office on May 31, 1940.

[1]The data from which this study is drawn are to be found in the Jessup Psychological Laboratory, George Peabody College for Teachers. The writer wishes to express his indebtedness to the group composing Coördinated Studies in Education, Incorporated, for the privilege of using these data.

area from which the children were drawn gives the data unusual significance.

The children included in this study were given the 11 tests constituting the *Unit Scales of Attainment* battery. The purpose of this battery is to measure school achievement. An educational age was determined on the basis of these scores, the median score being used as the educational age. The writer is aware of the criticisms that might be made of this method of determining educational age. It is true that a battery achievement test is not equally fair to all groups of children due to great differences in curriculum and teaching methods. It is the writer's belief, however, that the use of a median score reduces this injustice to a minimum since a child can obtain a very low score on a given test, or several tests, due to the absence of this subject from his curriculum, and still not have his educational age seriously affected.

Two groups were selected. The *accelerated* group is comprised of those children whose educational ages are one year or more in excess of their mental ages. The *retarded* group is made up of children whose educational ages are one year or more lower than their mental ages. These two groups are compared for the purpose of determining, if possible, factors which may enter into the relative acceleration of one group and the relative retardation of the other.

The accelerated group comprises 1,078 children while the retarded group includes 756 children.[2] That the retarded group is also slightly retarded relative to the accelerated group as regards their progress in school is indicated by a comparison of the two groups on the basis of chronological and mental age. The retarded group is older at each grade level, excluding the fourth grade where no differences were found. These differences ranged from .20 to .57 years for the boys and from .10 to .24 years for the girls. These differences, while small, are consistent. The mental ages of the retarded children are also greater, ranging from .23 years at the fifth grade level to .89 years at the eighth grade level. The differences in educational age range from 2.00 years to 2.59 years for the several grades.

Table 1 indicates that more educationally accelerated children are found in the 115-119 interval, whereas more retarded children are

[2]It is impossible at the present time to state how this distribution compares with that found at other levels of intelligence since this gifted group is the only one for which this educational age has been determined.

TABLE 1

A Comparison of the Percentage of Educationally Accelerated and Retarded Children Found in the Various *IQ* Groups

IQ interval	Boys		Girls	
	Accelerated	Retarded	Accelerated	Retarded
115-119	45.0	31.7	51 1	40.0
120-124	36 2	34 0	29 1	26 3
125-up	18 8	34 3	19 8	33 7

found in the group which includes those whose *IQ*'s are 125 or higher. The differences in the lowest and highest intervals are large enough to possess statistical reliability. This is another bit of evidence pointing to the greater retardation of the more intelligent children since, as far as this group of gifted children is concerned, the amount of retardation found at a given level of intelligence increases as intelligence increases.

Personality Traits

The children included in this study were rated by teachers on the basis of a list of 70 personality traits. This rating was to be done before any tests were given to the children. These traits have been rated by mental hygienists (1) and the differences between the accelerated and retarded groups are most illuminating when considered in the light of these ratings (Table 2).

Statistically reliable differences are found on 17 traits, 11 of these traits being credited more frequently to the educationally accelerated group while six are ascribed more frequently to the educationally retarded group. It is significant to note the ratings of the traits on which these reliable differences are found. Of the 11 reliable differences favoring the accelerated group, four of the traits were rated "5," or highly desirable to mental health, by the mental hygienists. Six of these traits were rated "4," indicating that the traits are considered to have some hygienic value but not as much as some others. One of these 11 traits was rated "3," indicating that the trait is considered neither desirable nor undesirable from a mental hygienic viewpoint. Of the six traits ascribed by teachers more frequently to the retarded group and on which statistically reliable differences were found, one was rated "3," and six were rated "2," that is, as being a trait that was considered to be probably undesirable or harmful.

TABLE 2

A SUMMARY OF THE TRAITS ON WHICH STATISTICALLY RELIABLE OR NEAR-RELIABLE DIFFERENCES ARE FOUND, TOGETHER WITH THE PERCENTAGE OF EACH GROUP TO WHOM THE TRAIT IS ASCRIBED

Critical ratios of the differences, based on probable errors, are given.

Traits	Ratings	Accelerated	Retarded	*CR*
Dependable	5	70.5	50.5	12.3
Honest	5	48.0	35.9	7.2
Original	5	45.2	18.9	15.7
Self-reliant	5	28.7	13.9	10.7
Ambitious	4	66.8	44 0	13.6
Artistic	4	21.4	16 6	3 5
Investigative	4	28.8	11 8	12.8
Leader	4	25.7	16.2	6.9
Persistent	4	25.6	15.9	6.7
Polite	4	49.8	43.4	3 8
Precocious	4	25.8	10 7	11.3
Systematic	4	13 6	7 5	5.5
Tidy	3	39 3	32.1	4.4
Whispering	3	6 2	10.2	4 0
Inattentive	2	3.7	8.7	5 4
Lack of interest in work	2	1.8	4.9	4 4
Lazy	2	1.6	4.1	4.0
"Quitter"	2	.7	3 4	5.1
Slovenly	2	.5	3 1	4.8

Eight traits out of the total list of 70 were rated "5" by the mental hygienists, and, interestingly, each of these traits was ascribed more frequently to the accelerated group than to the retarded group. The traits on which the differences are too small to be statistically reliable are *friendly, happy, likes jokes,* and *self-controlled.* Eleven traits out of the total group of 70 were rated "4" by the mental hygienists, and only one of these, *adventuresome,* was credited more frequently to educationally retarded children. The other traits of this group on which the differences are only slightly favorable to the accelerated group are *physically energetic,* and *generous.*

The traits which are rated by the mental hygienists as having the greatest value for mental health and on which the retarded superior group fails to a striking degree to measure up to the accelerated superior group are *dependability, originality, self-reliance,* and *investigativeness.* These are traits which are highly valued, not only by mental hygienists, but by people in general and they frequently are associated with high intelligence. Accordingly, it is significant that critical ratios of from 10 to 15 are found on these traits. It is impossible to say just what the significance of these differences is.

It may be that these traits are not always associated with superior intelligence and that some superior children are retarded because they do not possess these traits. This, however, would only partially explain retardation since many educationally retarded superior children are rated by the teachers as possessing these traits. Again, it may be that the conditions which bring about the educational retardation also are responsible for the failure of these traits to appear in many cases. This, again, would only partially explain the retardation. It still would leave unexplained those cases where there is retardation but where the children also manifest these desirable traits.

There are some traits, rated "3," "2," or "1," or neutral, probably harmful, or definitely harmful, which are not ascribed to either one of the groups with sufficiently greater frequency to give statistically reliable differences but which, nevertheless, give differences which throw some light on the comparative personalities of the two groups. The educationally accelerated superior children, for example, are rated as being more impatient with others, this being the only undesirable trait which seems to be considered by the teachers as probably more characteristic of the accelerated than of the retarded group. On the other hand, retarded children are rated as possessing a number of undesirable traits to a greater degree than accelerated children. These traits, together with their ratings by mental hygienists, are listed below.

Sex-conscious	3	Physical Cowardice	2
Talkative	3	Pouting	2
Cute, "cocky"	2	Rude; impudent	2
Day-dreaming	2	Self-conscious	2
Disobedient	2	Stubborn	2
Dull	2	Suspicious type	2
Immature	2	Tardiness	2
Impetuous	2	Too easily frightened	2
Lying	2	Dishonest	1
Nervous	2	Over-sensitive about self	1
Over-critical	2	Unhappy; moody	1

Relative to the traits which are assigned to the accelerated children with sufficiently greater frequency to give statistically reliable differences, it is to be noted that they are, with one exception, traits which are rated as having definite hygienic or constructive values. On the other hand, those traits which are ascribed to retarded children with sufficiently greater frequency to attain statistical reliability are traits which are rated as possessing no hygienic value or as being

positively harmful. Also, with one exception, they are characteristics of such a nature that they probably interfere with success in school work. That is, these personality ratings are such that it seems legitimate to interpret them as indicating that educationally retarded superior children are definitely maladjusted as regards the school situation. The traits which were listed at the close of the previous paragraph seem to offer some indications that the maladjustment of the retarded children may even extend beyond the school situation to life in general.

The *BPC Personal Inventory* was given to grades five to eight, inclusive, the language involved in the inventory being judged too difficult for fourth graders. The accelerated group made lower scores, low scores denoting emotional stability, on the basis of comparisons at each grade level. These differences, however, are so small that there is no assurance that similar differences would be found on similar groups. It seems evident, then, that one is not justified in holding that the characteristics measured by this test are a factor in either retardation or acceleration. The differences are so small that it would be just as logical to attribute the higher scores attained by the retarded group to the fact that they are retarded as to hold that the traits measured by the test are a cause of the retardation. That is, the higher scores made by the retarded group might be just as well interpreted as an effect of the retardation as to be considered as pointing to causes of retardation.

The teachers were asked to indicate which children they considered to be mentally retarded, problems, or geniuses. No boys in either group were checked as retarded whereas three girls in the retarded and two in the accelerated group were checked as mentally retarded by their teachers. Twelve children in the accelerated group, eight boys and four girls, and 13 in the retarded group, nine boys and four girls, are listed as problem children. This would appear to indicate that the educationally retarded children do not appear as clear-cut problems to the teachers any more frequently than educationally accelerated children. Fourteen children in the retarded group, four boys and ten girls, and 55 children in the accelerated group, 25 boys and 30 girls, are rated as geniuses. It does seem clear, though, that the accelerated children are presenting far more evidence of their superior ability to the teachers than retarded children since 5 per cent of the former and only 1.8 per cent of the latter are listed as geniuses.

Extra-Curricular Activities and Hobbies

The teachers were asked to select from a list of 10 extra-curricular activities the ones in which each child was interested. These activities are music, organized sports, unorganized sports, dramatics and forensics, academic clubs, avocational clubs, social clubs, boy and girl scouts and campfire girls, service clubs and student government. The differences in the interests of the two groups are not great.

The boys and girls of the educationally accelerated group have a greater interest in music than those of the educationally retarded group. Twenty-three per cent more of the boys and 10 per cent more of the girls of the accelerated group participated in the music activities of the schools. These differences are not statistically reliable.[3] Fifty-five per cent more of the retarded boys are listed as participating in organized sports. This difference is reliable. The only other difference which is statistically reliable is that of the boys' interest in service clubs. Over twice as many accelerated boys as retarded boys were listed as participating in this type of activity. Sizable differences are found in only three other traits. Thirty-two per cent more accelerated boys are listed as being interested in boy scouts, 49 per cent more of the retarded girls are listed as being interested in avocational clubs, and 54 per cent more accelerated girls in service clubs. All other differences are quite insignificant.

One factor that mitigates against the finding of significant differences between the groups on extra-curricular activities is what the writer believes is a misinterpretation of the meaning of extra-curricular activities on the part of the teacher. If ratings on extra-curricular activities are to be of any significance they must deal with activities in which the children are free to participate voluntarily. This does not seem to be the case in many instances since every child in the room is listed as participating in certain extra-curricular activities, indicating, it would seem that they are compulsory activities. Insofar as this is the case, it is not to be expected that any differences would be found between the groups.

A list of 21 hobbies was given the teachers and they were asked to list those in which each child was interested. Statistically reliable differences were found between the interests of accelerated and re-

[3]These differences are not reliable because of the small number of cases. Extra-curricular activities were not listed for many children. It was not deemed advisable to combine boys and girls into one group because of large sex differences.

tarded children on six hobbies. The educationally accelerated group is shown as possessing greater interest in four of these—reading novels, reading science, history and biography, building things, and collecting. The retarded group is listed as having greater interest in sewing, and the doing of household tasks.

The sex differences are of some interest. A list of hobbies has been compiled on which either the accelerated or retarded group show as much as a 10 per cent greater interest than the other group. On this basis, the educationally accelerated boys show a greater interest in reading novels, reading history, science and biography, listening to the radio, dramatics, playing make-believe games, religious activities, building things, traveling, and collecting things. The retarded boys show a greater interest in both quiet and active games, sewing, driving cars, and working, as in stores, on farms, and the like. It seems reasonable to conclude that the accelerated boys are more interested in hobbies that are intellectual in nature, that require some intellectual originality and ingenuity, that require broader interests, whereas those that are retarded are more interested in non-intellectual hobbies, in the motor-type of activities.

The situation is somewhat different as regards the girls. The hobbies that the educationally accelerated girls are more interested in are reading novels, reading history, science, and biography, quiet games, building things, scouting, and collecting; whereas the educationally retarded girls are more interested in active games, listening to radio, housework, going to shows, traveling, and working. Thus, the accelerated girls are also more interested in the hobbies that are somewhat more intellectual in nature and which require some greater degree of originality and ingenuity. The educationally retarded superior girls, in turn have greater interests in the more active, motor types of hobbies. On the other hand, the fact that they are more interested in going to shows, listening to the radio, and traveling may be taken to indicate that their interests are as broad as those of the accelerated group, but that they are more inclined to satisfy them in ways that require the minimum of intellectual effort.

Family Background

The family and home background has been shown many times to be an important factor in the general adjustment of the child. This

is particularly true regarding school achievement, which is the major interest in this study. A number of items of information are available on these matters relative to the children whom we are considering here.

The occupational status of the father gives some picture of the cultural status of the home. The fathers' occupations were classified according to the Terman-Taussig classification. Class 1 includes the professional group, Class 2 the business and managerial, Class 3 the skilled workers, Class 4 the semi-skilled workers, and Class 5 common laborers. Table 3 presents evidence that the occupations of

TABLE 3

THE DISTRIBUTION OF THE FATHERS' OCCUPATIONS OF EDUCATIONALLY ACCELERATED AND RETARDED SUPERIOR CHILDREN SHOWING THE PERCENTAGE OF THE FATHERS ENGAGED IN EACH OCCUPATIONAL CLASS, GIVING DIFFERENCES AND CRITICAL RATIOS BASED ON PROBABLE ERRORS OF THE DIFFERENCE

Occupational classifications	Accelerated	Retarded	*Diff.*	*CR*
1	13.8	5.0	8.8	8.8
2	38.7	31.8	6.9	4.1
3	33.8	34.4	.6	
4	5.3	12.6	7.3	6.7
5	6.5	12.8	6.3	5.6

the fathers of the children in the accelerated group fall definitely into higher classifications. It is to be noted that all these differences possess statistical reliability except in the case of Class 3. Four per cent of the families of the accelerated children were, or had been on relief while 8.9 per cent of the families of the retarded group had had relief. This difference is also statistically reliable. Eight and four-tenths per cent of the mothers of both groups were listed as working, indicating that the mother's working is not a factor in either educational retardation or acceleration.

The teachers were asked to rate the home background by rating economic status as Superior, Average, or Inferior, taking as a basis that the rating for the country at large should be: superior, 25 per cent; average, 50 per cent; inferior, 25 per cent. They were asked to proceed on the same basis in the parents' attitudes toward the child and home. They were instructed not to make the ratings if sufficient information was not available. The fact that the ratings were not made in a large number of cases apparently indicates that

TABLE 4

PERCENTAGE OF HOMES OF EDUCATIONALLY ACCELERATED AND RETARDED CHILDREN RATED IN EACH ECONOMIC CLASS, TOGETHER WITH DIFFERENCES AND CRITICAL RATIOS BASED ON PROBABLE ERRORS OF THE DIFFERENCES

	Accelerated	Retarded	*Diff.*	*CR*
Inferior	7.5	17.1	9.6	7.2
Average	66 0	68.7	2.7	—
Superior	26.6	14 3	12.3	8.1

the teachers followed the instructions. Table 4 also shows that the children in the accelerated group have more favorable home backgrounds. The differences in the homes rated inferior and those rated superior are large and significant. Table 5 reveals even greater differences favoring the accelerated group.

TABLE 5

RATINGS OF PARENTAL ATTITUDES OF EDUCATIONALLY ACCELERATED AND RETARDED CHILDREN SHOWING THE PERCENTAGE GIVEN EACH RATING, TOGETHER WITH DIFFERENCES AND CRITICAL RATIOS BASED ON PROBABLE ERRORS OF THE DIFFERENCES

	Accelerated	Retarded	*Diff.*	*CR*
Inferior	2.2	6.4	4.2	5.0
Average	43.4	59.3	16.9	8.6
Superior	54.4	34 4	20.2	10.7

A socio-economic rating was obtained based on a rating scale which was somewhat influenced by the Sims *Socio-Economic Scale.* The factors evaluated by the scale are father's occupation, the possession of a telephone, auto, radio, regular servant, regular newspaper, and the room-person ratio. Four and seven-tenths per cent of the homes of accelerated children rated scores from zero to three, inclusive, whereas 11.1 per cent of the homes of retarded children were given these ratings. On the other hand, 33.2 per cent of the homes of accelerated children received the highest ratings, 10 to 16, inclusive, whereas only 21.5 per cent of the homes of retarded children received these ratings. These differences also are statistically significant.

The accelerated children come from slightly smaller families. Fifty per cent of the accelerated children and only 39 per cent of the retarded children come from families in which there are only one or two children in the home. Again, 12 per cent of the acceler-

ated children are "only children" and 30.8 per cent of the same group are first children, whereas only 8.4 per cent of the retarded children are "only children" and 22.4 per cent are first children. These differences are statistically reliable except in the case of "only children" where the differences approach the commonly accepted standard of reliability. Retarded children appear more frequently than accelerated children in all family sizes of four or more children and in all birth ranks of third or higher.

The writer does not believe that these facts can be interpreted as meaning family size and birth rank are factors in acceleration and retardation. Professional people and those of the managerial group have somewhat smaller families than those in the semi-skilled and unskilled laboring classes. Since more of the educationally accelerated children come from the former group and more of the educationally retarded from the latter groups, the differences in family size and birth rank which are found between the two groups under consideration probably are to be anticipated.

The writer believes that the differences found in the family backgrounds of the two groups point to possible causes of retardation and acceleration. It seems reasonable to believe that the higher ratings of fathers' occupations and socio-economic status of the homes of accelerated children reflects a cultural and ideological superiority which is probably a very important factor in the superior achievement of these superior children, whereas the lower ratings of the homes of the retarded children reflect a cultural deficiency which is a factor in their educational retardation. The more favorable parental attitudes which the accelerated children enjoy is without much doubt another factor in their superior achievement.

The purpose of this study has been to compare a group of educationally accelerated superior children with a group of educationally retarded superior children relative to possible differences in personality traits, interests, and home background in the hope that some information might be obtained as to possible causes of educational acceleration and retardation of superior children. It appears to be significant that the educationally accelerated group is credited with possessing more desirable personality traits, interests that are intellectual in nature, and superior home backgrounds. Especially significant is the frequency with which the traits of dependability, originality, self-reliance, and investigativeness are assigned to educationally accelerated children. The educationally retarded group,

on the other hand, appear to possess less desirable personality traits, to tend toward interests that call for a degree of motor activity, and to come from relatively inferior homes.

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Murray State Teachers College
Murray, Kentucky

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The Journal of Genetic Psychology, 1941, 59, 219-223.

A STUDY OF THE PROGNOSTIC VALUE OF THE MERRILL-PALMER SCALE OF MENTAL TESTS AND THE MINNESOTA PRESCHOOL SCALE*

Department of Psychology, University of Pittsburgh

RUTH DE FOREST

Since test-retest correlations on preschool scales, with the retest using either the same preschool scale or another scale for older children, have been low; and since the reliability and validity of existing preschool scales are doubtful, this study was instigated. It was to test the predictive value of the *Merrill-Palmer Scale of Mental Tests* and of the *Minnesota Preschool Scale* that this research was undertaken.

Of 250 children in nursery school who had been given the *Merrill-Palmer Scale* by students in classes in the Testing of Preschool Children at the University of Pittsburgh over a period of eight years, 170 were available in 1938-39 for testing with the *Revised Stanford-Binet, Form L.* Of about 75 children who had been given the *Minnesota Preschool Scale* over a period of five years by the same students, 44 were available for testing with the *Revised Stanford-Binet, Form L.*

In order to answer the question of reliability of *students'* tests, test and retest on Merrill-Palmers given by students were correlated. Fifty-two children had had two Merrill-Palmers administered by students. For this group, the age range of which was 24 to 63 months and the interval between the tests from four to 24 months, r is $.60 \pm .06$, using standard deviation values for correlation measures. Stutsman (1), between test and retest on the Merrill-Palmer for

*Received in the Editorial Office on April 5, 1940.

207 children between 24 and 60 months, the time interval being from six to nine months, got a correlation of $.588 \pm .031$, using standard deviation values for correlation measures. The CR_{PE} for these two r's, Stutsman's and the correlation obtained in this study, is .18. This indicates that the difference between the two correlations is not statistically significant, there being 45 chances in 100 that there is no true difference. Hence, we can safely assume that the *students' tests* used are as reliable as intelligence tests administered by an experienced examiner.

The intervals between the preschool test and the Stanford-Binet ranged from one to 88 months. The chronological ages of the children examined on the Merrill-Palmer were from 24 to 63 months, in accordance with Stutsman's stipulations for the valid use of the scale (2).

Stutsman recommends the use of the standard deviation with the Merrill-Palmer Scale rather than the *IQ* because the *IQ* range at various age levels at the same standard deviation placement is very great. One cannot be sure, however, that it is the *IQ* and not the standard deviation that is at fault, for Stutsman's standard deviation curves have been smoothed considerably, as one can see by referring to her printed raw data. For this reason and since the *IQ* is used with the Binet, an examination of the *IQ* and standard deviation measures on the Merrill-Palmer was made. Correlation of test and retest for 52 cases, using standard deviation values as the measure of intelligence, is $.60 \pm .06$. When *IQ*'s are used as the measure, with the same 52 cases, the correlation is $.59 \pm .06$. The CR_{PE} for these two r's is .1. This critical ratio is not significant since there are 47 chances in 100 that there is no true difference. Consequently, the *IQ* was used as the measure of intelligence to be correlated throughout the study. The Pearson product-moment method of correlation was used.

The range of *IQ*'s on the Merrill-Palmer for this group of 170 children is 69 to 169; on the Binet, the range is 58 to 160. The group is probably a select one, for the average *IQ* on the Binet is 113.53; on the Merrill-Palmer, 113.00.

The *IQ*'s on the Merrill-Palmer correlated with the *IQ*'s on the Binet to the extent of $.55 \pm .04$. The change from the Merrill-Palmer *IQ* to the later Binet *IQ* was five intelligence quotient points or less in 34.7 per cent of the cases; 10 points or less in 56.5 per cent of

the cases. More than 10 points increase from the Merrill-Palmer *IQ* to the Binet *IQ* occurred in 24.7 per cent of the cases; more than 10 points decrease, in 18.8 per cent. The changes in intelligence quotient points from the Merrill-Palmer to later tests with the Binet are given in Table 1.

TABLE 1

CHANGES IN *IQ* POINTS FROM THE MERRILL-PALMER TESTS TO LATER STANFORD-BINET TESTS

Changes in points	Number	Percentage
over +20	12	7.1
+16 to +20	16	9.4
+11 to +15	14	8 2
+ 6 to +10	21	12 4
+ 1 to + 5	27	15.9
no change	6	3.5
— 1 to — 5	26	15.3
— 6 to —10	16	9 4
—11 to —15	8	4.7
—16 to —20	7	4.1
over —20	17	10.0
Total	170	100 0

Median change in *IQ* points	9.9
Mean change in *IQ* points	12.1

The size of the interval between Merrill-Palmer and Binet examinations proved not to be significant. The correlation between the Binet and the Merrill-Palmer when the interval between the examinations was seven months or less was $.54 \pm .07$; when the interval was more than seven months, r was $.58 \pm .04$. The difference between these two r's is not statistically significant.

The younger the child at the time of the administration of the Merrill-Palmer, the higher the correlation with the Binet proved to be. Table 2 gives the correlations between Binet and Merrill-Palmer *IQ*'s at the various age levels

There were 44 children to whom Minnesotas were given. The Minnesota Total *IQ* correlated $.56 \pm .07$ with the Binet, the Minnesota Verbal *IQ* correlated $.55 \pm .07$ with the Binet; the Non-Verbal *IQ*, $.38 \pm .09$. Table 3 contains a tabulation of differences in *IQ* points from the Minnesota Total *IQ* and the Minnesota Verbal *IQ* to the later Binet *IQ*.

TABLE 2

RELATIONSHIPS OF THE STANFORD-BINET SCALE AND THE MERRILL-PALMER SCALE AT VARIOUS AGE LEVELS

Age level at time of Merrill-Palmer	r	PE_r	N	Per cent improvement in prediction over chance
24-39	.71	04	57	29.6
30-45	.65	.04	85	24.0
36-51	.65	.04	102	24.0
42-57	.48	.05	94	12.3
48-63	.46	.07	64	11.2
51-63	.22	.09	46	2.0
24-63	.55	.04	170	16.5
24-42	.71	.04	77	29.6
43-63	.45	.06	93	10.7

TABLE 3

CHANGES IN POINTS FROM THE MINNESOTA TOTAL IQ AND THE MINNESOTA VERBAL IQ TO LATER STANFORD-BINET IQ'S

Changes in points	Number	Minnesota total IQ percentage	Number	Minnesota verbal IQ percentage
over +20	6	13.6	6	13.6
+16 to +20	3	6.8	2	4.5
+11 to +15	5	11.4	5	11.4
+ 6 to +10	3	6.8	4	9.1
+ 1 to + 5	9	20.4	7	15.9
no change	0	0.0	1	2.3
— 1 to — 5	5	11.4	5	11.4
— 6 to —10	2	4.6	4	9.1
—11 to —15	3	6.8	2	4.5
—16 to —20	3	6.8	5	11.4
over —20	5	11.4	3	6.8
Total	44	100.0	44	100.0

The average of the Minnesota Total IQ's and the Merrill-Palmer IQ's (44 cases) was correlated with the Binet IQ, with an r of .61±.06 resulting. The average of the Merrill-Palmer IQ and the Minnesota Verbal IQ correlated with the Binet to the extent of .62±.06.

Summary

1. Merrill-Palmer IQ's for the total age range correlated to the extent of $.55 \pm .04$ with later Binet IQ's.

2. Minnesota Total IQ's correlated to the extent of $.56 \pm .07$ with later Binet IQ's.

3. The Non-Verbal Minnesota IQ's correlated to a much less degree with later Binet IQ's than did any of the other IQ's obtained.

4. Minnesota Verbal IQ's correlated with the Binet to approximately the same extent as the Merrill-Palmer and the Minnesota Total IQ's.

5. The findings of the children studied here indicate that the younger the child at the time of the administration of the Merrill-Palmer the greater was the predictive value of the Merrill-Palmer for the Binet. The correlation for the two tests was lowered particularly at the introduction of test results for children who were more than 51 months of age at the time of the Merrill-Palmer.

6. The size of the time interval between Merrill-Palmer and Binet examinations proved not significant, as far as prediction of the second from the first is concerned.

7. The IQ seems as reliable as the standard deviation value on the Merrill-Palmer.

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721 North El Paso Street
El Paso, Texas

The Journal of Genetic Psychology, 1941, 59, 225-228

A COMPARISON OF NEGRO AND WHITE CHILDREN IN SPEED OF REACTION ON AN EYE-HAND COORDINATION TEST*

George Peabody College for Teachers

JOSEPH E. MOORE

The question of how to measure and interpret differences in speed of reaction among Negro and white subjects, which may or may not be due to "racial" differences remains at the present time unsettled. After reviewing the literature on racial differences Klineberg (2, p. 107) concluded that "There is evidence that the greater speed of performance of white children, which is responsible for better scores for time, is more probably determined by environmental, than by racial differences."

Experimental attacks have already thrown some light on the question of speed differences among Negro and white subjects. Young children have been used so that specific environmental training would have had a shorter time to operate. Lambeth and Lanier (3) compared a group of 30 twelve-year old Negro school children with 30 twelve-year old white subjects on a number of tests among which were two speed tests (*Minnesota Tapping*, and *Minnesota Speed of Movement*) involving to some degree eye-hand coördination. The differences favored the white subjects but neither was statistically reliable.

In a more recent investigation Rhodes (4) studied a group of 80 Negro children, 20 at each of four age levels between 2½ years and 5½ years. By using the same tests (walking a line, needle threading, the three hole test, and stylus tapping) as employed by Goodenough and Smart (1) on white children, Rhodes was able to make comparisons with white children of the same age grouping. No statistically significant difference was found. Negro children were superior at all four age levels on line walking and needle threading On stylus tapping the 4½ and 5½ year old Negro children excelled the white subjects of the same age. The performance of the Negro subjects was much more homogeneous, as reflected by the smaller

*Received in the Editorial Office on May 6, 1940

standard deviations, than the white groups with which they were compared. No mention was made by Rhodes as to the sex distribution of her subjects.

The present study employs a group of young children upon whom the social-milieu has had a relatively short time to operate. The white subjects were 43 boys and 49 girls, the Negro subjects consisted of 39 boys and 42 girls. The age of the subjects was set between the year six and seven years five months. The schools from which the subjects came were selected so that pupils from a white elementary school in the city of Nashville, Tennessee, or the County of Davidson would be compared to Negro pupils of a similar district.

The measuring instrument was the eye-hand coördination test developed by the writer.[1] The test is relatively simple. It is composed of a rectangular box in the top of which are bored 32 round holes of the same size in rows of eight. In a slot at the end of each row of holes are placed eight marbles. Each group of eight marbles is of a different color. The subject after going through the first row for practice, is timed in placing the marbles in the holes one at a time consecutively. The test-score is the total time in seconds it takes the subject to complete the test three times.

The subject sits while taking the test. The height of the test from the floor in the first grade room was regulated so that a child would be able to reach the marbles without being forced to hold his elbows up and out from his sides.

The test was given to all pupils in their own school building. Two subjects were taken from the room at a time and tested. The different colored marbles and the simplicity of the test enabled one to establish rapport rather quickly and easily.

The number of subjects is so small that it may be questionable whether one is justified in applying statistical techniques based upon random sampling to data so highly selective. The following statistical evaluation is presented with an awareness as to its possible limitation. Table 1 presents the data for both race and sex.

The difference between the Negro and white girls is not statistically significant. It will be observed, however, that the sampling

[1]A complete description with data on the standardization of the test can be found in *J. Appl. Psychol*, 1937, **21**, 668-672.

TABLE 1

MEANS, MEDIANS, STANDARD DEVIATIONS, AND CRITICAL RATIOS FOR SPEED OF EYE-HAND COÖRDINATION OF WHITE AND NEGRO CHILDREN BETWEEN THE AGE OF SIX AND SEVEN YEARS FIVE MONTHS

Subjects	*N*	Mdn	Mean	*SD*	Mean	*CR*
Total Negro	81	159.7	161.8	25.10	5.30	1.51
Total White	92	149.59	156.5	20.15		
Negro Girls	42	168.00	163.10	26.75	8.55	1.72
White Girls	49	148.21	154.55	19.15		
Negro Boys	39	156.5	160.3	23.65	1.40	.28
White Boys	43	151.5	158.9	21.40		

*All scores are in terms of seconds, hence the smallest scores represent the fastest reactions

of white girls is negatively skewed while that of the Negro group is positively skewed. (The ordinary interpretation of skewness is reversed in these data for the high score is the unfavorable or slow time and would be placed at the left—reading from high to low on the baseline of the curve.) It would appear that in this sampling the Negro girls cluster at the slow end of the scale and represent those who respond slowly on the test. The group of white girls seems to be drawn more from those who perform rapidly on the test.

The samplings of the Negro and white boys are negatively skewed. There is little difference in the extent of skewness of the two groups when the measures of central tendencies are compared. The smallness of the two groups did not seem to warrant the application of any of the more exact measures of skewness. These data indicate that on the type of speed measured by the eye-hand coördination test white girls excel Negro girls and white boys excel Negro boys. None of the differences was statistically reliable.

When a comparison is made between white boys and white girls the difference favors the girls, but the critical ratio is only 1.03. For the comparison of Negro boys and Negro girls the differences favor the boys, however, the difference between the means is only .50 times its standard error.

Conclusions

In as far as the eye-hand, coördination test used in this study is a fair measure of the speed of movement of children between the ages of six and seven years five months there is no statistically reliable difference between the Negro and white subjects employed in this investigation.

White children responded faster on the test than did the Negro subjects. White girls were superior to Negro girls and white boys excelled Negro boys.

Negro boys were superior to Negro girls but white girls surpassed white boys on the eye-hand coordination test. The Negro girls seemed to be drawn from a group which responded unusually slowly on the test and may reflect inadequacy of sampling.

The superiority of the white subjects in this study is in agreement with findings of Lambeth and Lanier (3) on their twelve-year-old subjects, but fail to support the finding of Rhodes (4) who used children under six years of age. The tests, however, were not the same and might have measured markedly different speed factors.

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George Peabody College for Teachers
Nashville, Tennessee

The Journal of Genetic Psychology, 1941, 59, 229-236

BOOKS

The *Journal of Genetic Psychology*, the *Journal of General Psychology*, and the *Journal of Social Psychology*, will buy competent reviews at not less than $2 per printed page and not more than $3 per printed page.

Conditions. Only those books that are listed below in this section are eligible for such reviews. In general, any book so listed contains one or more of the following traits: (*a*) Makes an important theoretical contribution; (*b*) consists largely of original experimental research; (*c*) has a creative or revolutionary influence in some special field or the entire field of psychology; (*d*) presents important techniques.

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CRITICAL REVIEWS OF RECENT BOOKS

(*Maier, N. R. F. Studies of Abnormal Behavior in the Rat. New York: Harper, 1939. Pp. 81.*)

REVIEWED BY PETER HAMPTON

Experimental neurosis, i.e., the neurotic state set up experimentally, was accidentally discovered in Pavlov's laboratory in 1914 by one of his co-workers in a study of discrimination with dogs. Since then experimental neurosis has also been induced in sheep, pigs, mice, pigeons, monkeys, cats, and rats. Of all these creatures, the rats have presented the most difficult problem to the psychologists, because they seem to adjust better than any other animal to conflict situations. It is only within the last few years that rats have been successfully put into a neurotic state.

Of the studies on abnormal behavior in rats, reported by Cook, Maier, Humphrey and Marcuse, and the Morgans, those of Maier seem to be the most exhaustive and detailed. Unlike some of the other investigators of experimental neurosis, particularly Pavlov, who used the conditioned response method (in which the number of alternate presentations of the negative and positive stimuli are increased), Maier used a modified form of the discrimination technique (in which the difference of alternate presentations of stimuli is decreased). He trained his rats to discriminate between two cards, one with a black circle and a white background, which when jumped at by the rat opens up and permits the animal to reach food; and the other, with a white circle and a black background, which when jumped at by the rat remains in a vertical position and as a result dumps the rat into a net placed below. When the rats had learned to discriminate between these two cards, Maier changed the cards so that the rats no longer were able to use the previously learned cues to make a choice of the card which would lead them to food. The rats thereupon refused to jump. Maier then applied an air blast or an electric shock to the rats and thus forced them to jump.

At this stage of the proceedings, either before jumping was forced or after, a number of the animals developed neurotic attacks.

However, these attacks occurred only when the air blast was used to force jumping and never with shock alone. Maier explains this fact by stating that when shock was applied the rats managed to avoid the issue of jumping. This was not true with the air blast, for it was continuous. On some occasions the rats had a neurotic attack merely from seeing and hearing other rats being forced to jump by the air blast, suggesting, therefore, that neurotic attacks in rats are sometimes brought on when no conflict situation exists.

Recent investigations at Queen's University by Humphrey and Marcuse place doubt upon the possibility of putting a rat into a neurotic state without producing a conflict situation. Reporting on his work at the last meeting of the Canadian Psychological Association, Humphrey pointed out that he and Marcuse had discovered that adaptation to the stimulus situation plays a very decided part in the rat's susceptibility to neurotic attacks. Wild rats, rats which have had little handling, are much more susceptible to neurotic attacks than tame rats. As a matter of fact, the tamer the rat the less likelihood there is for the rat to succumb to a conflict situation and fall into a neurotic state. But, tame or wild, there was evidence in Humphrey and Marcuse's studies that all the rats which developed a neurotic attack showed clear signs of undergoing a conflict. Thus the rats which in Maier's studies fell into a neurotic state by merely seeing and hearing other rats being put through the discrimination pace, in actuality probably shared in the conflict situation in which the former rats found themselves.

There is a possibility that Maier's rats, which he claims developed a neurotic attack when hearing the air blast, actually underwent a conflict situation. These rats acted *as if* they themselves were forced to discriminate between the two cards and jump towards one of them, with the result that they fell into a neurotic state of behavior. We observe the same thing in hypnosis. In some cases people who merely watch others being hypnotized fall into the hypnotic state. They act *as if* they were the ones to whom the hypnotist directs his suggestions, and as a result succumb to these suggestions. If this procedure is true with rats, and research carried on at the psychology laboratory at Queen's University is pointing that way, new possibilities for experimental neurosis may be at hand.

In some cases the resulting abnormal behavior was classified by Maier as nervousness as opposed to neurotic behavior. Thus some of Maier's rats showed "marked fear reactions," but did not actually

develop a neurotic attack. Only when the following behavior syndrome was evidenced was the animal regarded as neurotic. The syndrome consists of "an active phase, which is characterized by hyperactivity, convulsions, hopping movements and tics, and a passive or coma-like phase during which the animal manifests various degrees of waxy flexibility." Maier notes that this twofold pattern of abnormal behavior shown by the neurotic rat is very similar to an epileptic seizure. The rats which showed an extreme fear reaction but did not succumb to the conflict situation, were, according to Maier, actually saved from the neurotic attack by their nervousness. Maier concludes from this that the emotional rat is much less susceptible to experimental neurosis than the phlegmatic rat.

The manic-depressive characteristics of the rat's neurotic behavior have been (as far as the reviewer is aware) corroborated by all the investigators now working on this problem. But there is no such unanimity of opinion with regard to the claim, made by Maier, that the emotional rat is less susceptible to a neurotic attack than the more phlegmatic rat. Humphrey and Marcuse intimate that the opposite seems to be true. They found that of 34 "phlegmatic" rats, only one had a neurotic attack on the first day stimulation was introduced; while of 34 "emotional" rats, 22 developed neurosis the first day (G. Humphrey and F. Marcuse, "*Factors involved in the immunity of rats to convulsions under intense auditory stimulation.*" Bulletin of the Canadian Psychological Association, October, 1940). Apparently more information is necessary on this point before we can form a definite conclusion regarding the effect of emotionality upon neurotic attacks.

A large section of Maier's monograph is devoted to the case histories of the neurotic rats which he studied. A discussion of these cases brings out a number of subsidiary facts regarding the induction of abnormal behavior in rats. Age, brain injuries, sex, and pigmentation, according to Maier, have no relation to the rat's susceptibility to neurotic attacks. Rats varying in age and extent of brain injury, and rats of different colors and different sexes, all fell fairly easily into the neurotic state.

In this connection too it seems advisable to withhold final judgment with regard to the relation between the factors mentioned above and the rat's susceptibility to neurotic attacks. Statistically the number of rats thus far studied in an attempt to understand the neurotic behavior of rats are too small to warrant elaborate generalizations.

There is no doubt, of course, that Maier's studies of abnormal behavior in the rat are a milestone in the study of experimental neurosis; and as such his monograph will retain an important place in psychological literature. Comparing Maier's work on experimental neurosis in rats with that which had gone before, three differences stand out prominently:

First, Maier used the Lashley jumping apparatus in bringing about neurotic attacks. The established preferences were in terms of reward and punishment. This method departs from the classical conditioned response technique "in which an unconditioned stimulus is used to determine the response."

Second, compressed air rather than shock was used to force the animal to jump from the Lashley jumping platform to the windows containing the cards which served as discrimination stimuli.

Third, the restraint suffered by the rats was of a psychological rather than a physical nature. No harness was used. While the jumping platform was enclosed, it did not entirely prevent the animal from escaping the conflict situation by jumping to the floor. Thus "depriving the animal of acquired modes of response was from the beginning a psychological rather than a physical restriction of behavior."

Department of Psychology
University of Manitoba
Winnipeg, Canada

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(There will always be two pages of book titles, listed in the order of receipt, i.e., the most recently received books will be found at the end of the list.)

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Two volumes per year

December, 1941
Volume 59, Second Half

Founded by G. Stanley Hall in 1891

THE PEDAGOGICAL SEMINARY AND JOURNAL OF GENETIC PSYCHOLOGY

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The Journal of Genetic Psychology, 1941, **59**, 239-247.

MOTOR CORRELATES OF INFANT CRYING*

Clinic of Child Development, Yale University

LOUISE BATES AMES

A. THE PRESENT INVESTIGATION

As long ago as 1873 Darwin, in his book *The Expression of the Emotions in Man and Animals*, described in accurate detail bodily and facial patterns by which different animals including man express such emotions as joy, rage, grief, and terror. One whole chapter is devoted to the facial behavior which marks the crying of infants and children. His description of this facial behavior may be summarized as follows: The infant when crying closes his eyes firmly so that the skin around them is wrinkled and the forehead contracted into a frown. The mouth is widely opened with the lips retracted in a peculiar manner, which causes the corners to be drawn down and the mouth to assume a squarish form, and the gums or teeth to be more or less exposed. The contraction of the orbicular muscles leads to the drawing up of the upper lip and the drawing upwards of the flesh of the upper part of the cheeks which runs from near the wings of the nostrils to the corners of the mouth and below them. Darwin observed in one of his own infants that from the 8th day on the first sign of a screaming fit was often a little frown, reddening of the face, contraction of all muscles around the eyes, and opening of the mouth.

Since Darwin's publication relatively little study has been made of the crying behavior of infants, and no report has been found in the literature which includes as detailed an account of general body activity in crying as Darwin gave of facial activity. Borgquist (2) analyzed the crying act (adults and children) into its component physiological parts, interpreting the series of movements observed in crying as a connected function, part of a process involved in the act of rejection of food, suggesting physiological cessation and even reversal of the will to live, but he does not describe specifically the

*Accepted for publication by Arnold Gesell of the Editorial Board, and received in the Editorial Office on June 8, 1940.

bodily attitudes which accompany crying beyond characterizing them as attitudes of resignation and abasement.

As Hunt (5) has pointed out, one of the most conspicuous gaps in our knowledge of emotional behavior concerns the existence of definite behavior patterns in the various emotions. So far, little distinctive and predictable behavior has been discovered. The problem is rendered more significant by the fact that such innate responses as do exist in the organism at birth are soon altered by learning.

The present study aims to determine whether or not any specific motor behaviors, other than the traditional face-mouth behaviors described by Darwin, characterize the crying of the human infant during the first year of life. If so, are these same behaviors seen in the non-crying infant, or do they solely characterize crying behavior?

We have selected infants as subjects for the present study because their crying behavior is less influenced or modified by individual experience than that of adults. The subjects are 13 of the "naturalistic" group of infants who were studied and photographed at the Yale Clinic of Child Development at monthly age intervals during their first year of life (4, vol. II, pp. 535-543). At the Clinic the children spent the day much as they would have done at home. They napped, ate, played, were bathed, etc. Each mother cared for her own infant. Physical conditions were kept standard. No specific stimuli were used to induce emotional behavior. Crying when it occurred was presumably spontaneous.

Of the many situations of everyday life in which these subjects were photographed, supine on floor and supine on bath table were selected for this study, since it is in the supine position that the child is freest to move his limbs during the first months.

Both crying and non-crying behavior were analyzed in detail for each age level when both occurred. All babies did not cry at all age levels, and age levels for which both crying and non-crying records were not available were omitted. For seven of the cases, records of from five to eleven age levels were available; for six additional cases, one or two age levels each. In all, 57 case-ages were available for study. The age range covered is from 8 to 48 weeks.

B. Characteristic Crying and Non-Crying Behavior Patterns

Five forms of behavior were found which commonly accompanied

crying and which occurred infrequently in non-crying. Hands-to-mouth behavior occurred about equally in both. The incidence of these six forms of behavior is indicated in Table 1.

TABLE 1

Crying behavior patterns	No. of times observed in Crying	Non-crying	Yule's coefficient of Association
1. More activity than in non-crying	42	0	1.00
2. Legs more active than arms	33	2	.94
3. Leg activity more unilateral than bilateral	41	6	.91
4. Legs more flexed than extended	37	7	.89
5. Foot to knee	15	6	.50
6. Hands to mouth	24	20	.14

Six kinds of behavior occurred more frequently in non-crying than in crying. The incidence of this behavior is indicated in Table 2.

TABLE 2

Non-crying behavior patterns	No. of times observed in Crying	Non-crying	Yule's coefficient of Association
1. Legs extend more than flex	3	43	.96
2. Leg activity more bilateral than unilateral	5	47	.96
3. Arms more active than legs	5	24	.76
4. Foot crosses over other ankle	4	13	.59
5. Tonic neck reflex	6	18	.59
6. Legs extend or semi-extend up	12	29	.57

The foregoing findings are presented graphically in the accompanying bar diagram (Figure 1). This diagram indicates clearly that the difference between general body activity in crying and non-crying is marked. It shows that differences are by no means limited to facial and vocal patterns.

In general it will be seen that *crying behavior* is characterized by vigorous limb activity, unilateral arm and leg behavior, greater leg than arm activity, strong flexor tendencies, and the breaking up or disorganizing of postures prevailing at the time of onset. *Non-crying behavior* is characterized by limb extension, bilateral postures, greater arm than leg activity, and holding of set postures.

The diagram shows the marked preponderance of most of the

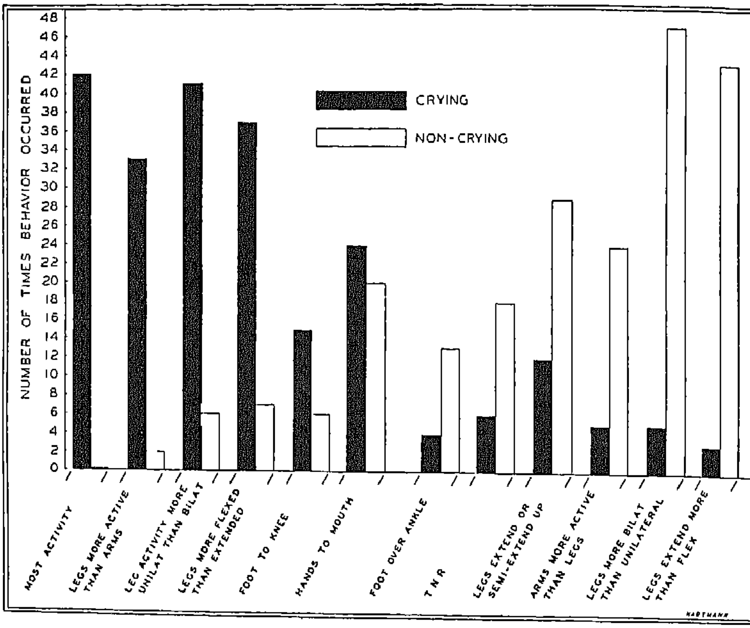

FIGURE 1
DIFFERENCES BETWEEN GENERAL BODY ACTIVITY IN CRYING AND IN NON-CRYING

behaviors in that kind of activity for which they are considered characteristic (crying or non-crying) over their occurrence in that kind of behavior for which they are considered not characteristic. Figure 2 contrasts crying and non-crying postures in one of our subjects, Boy *D*, illustrating the unilateral and flexor aspects of crying behavior.

C. Order of Limb Movements in Crying

Data on this subject were not entirely adequate, since the child was often crying when put down in the supine position and many of the records did not show the onset of crying behavior. Analysis of such records as were available suggests that there appears to be a somewhat standard pattern for the way in which crying starts. But after it has begun, it was not found possible to determine any tem-

FIGURE 2
Non-Crying and Crying in Boy *D* at 8 and 24 Weeks

poral or spatial limb pattern which is characteristic of all children or even of one child from age to age. As pointed out above, crying seems more to disorganize the patterns prevailing at time of onset than to produce an invariable pattern.

The general pattern characterizing the onset of crying is as follows: Forehead wrinkles just over inner corners of eyes, mouth opens, lines beside mouth deepen, tongue flattens and then troughs, nose flattens and eyes squint shut, legs become unilaterally active. Individual variations occurred, however. In one child the first indication of crying was very active unilateral leg flexion and extension, one leg flexing as the other extended. This was followed after about one second by the common facial crying pattern.

Examples (Tables 3 and 4) of the way in which crying started

TABLE 3

BOY *D*, 24 WEEKS, SUPINE ON FLOOR

Time in frames*	Behavior
0.00	Supine, not crying, arms and legs extended, mouth closed, eyes open.
0:04	Vertical wrinkle appears in forehead between eyes;** mouth opens, lines beside mouth deepen
1:00	Mouth opens wider, tongue flattens, one leg flexes.
3:04	Leg extends, tongue troughs, nose flattens and eyes squint shut. Child is crying hard by now, but arms have not participated.

*There are 16 frames to a second. Thus 3·04 equals 3 4/16 seconds.
**This agrees with Darwin's description.

TABLE 4

BOY *C*, 32 WEEKS, SUPINE ON FLOOR

Time in frames	Behavior
0:00	Chin puckers and eyes close.
0:02	Forehead wrinkles over inner corners of eyes, mouth opens, lines beside mouth deepen.
0:05	One leg flexes, mouth opens even wider.
0:10	Flexed leg extends while other leg flexes. Arms remain in extension.

in two of our subjects suggest the general order and timing. As will be seen, crying behavior usually begins rather suddenly. A non-crying child may be fully crying in as short a time as half a second. Three to four seconds is the more usual interval between the first outward sign of crying and full-fledged crying behavior.

D. Individualistic Patterns of Crying Behavior

In general the crying behavior of all subjects is much alike, even though crying is not patterned. However, some of the specific forms of behavior under discussion occurred to a greater extent in some children than in others (see Table 5). Furthermore, each child has certain individual ways of behaving which characterize his supine behavior throughout the whole age range, as is suggested in the following descriptions of the characteristic supine behavior of four of our cases.

Boy A is very active and extensor in non-crying supine. Legs extend up at each age from 16 through 36 weeks and trunk rolls to the side. When he *cries*, unilateral activity becomes very marked in both arms and legs at all ages, and legs are much more active than arms.

Boy C is perhaps most typical of all the group, his behavior being bilateral and extensor in non-crying with arms more active than legs, while in *crying* one foot comes to the other knee, arms move unilaterally, and a tendency toward flexor behavior with legs more active than arms prevails

Boy D maintains an extremely individual posture which is almost identical at 20, 24, 28, and 32 weeks. He lies with head lifted, arms bowed, though in extension, at shoulder height, legs extended and slightly bowed in, and feet lifted with toes of the two feet touching In *crying* he usually flexes one arm or brings both hands to his mouth, and brings one foot to the other knee. Is apt to roll trunk to one side.

Girl A presents a somewhat contrasting picture with her consistent tendency to extend both legs upward in non-crying Arms are very active, usually in extension. In *crying*, her hands usually come to her mouth, leg behavior is unilateral, and she "hummocks" her hips.

E. Conclusions

Motor behaviors which commonly characterize crying in the human infant include body postures as well as traditional facial patterns described by Darwin. Crying is characterized by marked limb activity, greater leg than arm activity, unilateral rather than bilateral and flexor rather than extensor movements, and the breaking up of postures prevailing at the time of its onset. These behaviors clearly

TABLE 5

SHOWING WHICH BEHAVIORS ARE MOST CHARACTERISTIC OF EACH CHILD

Percentage of Possible Age Levels at which Each Behavior Occurs in Each of the Main Cases

	Behavior	Boy *A*	Boy *B*	Boy *C*	Boy *D*	Girl *A*	Girl *B*	Girl *C*
Crying	Most activity in crying	87%	80%	71%	85%	81%	60%	40%
	Unilat. leg behavior	87	60	57	85	63	80	60
	Legs fl more than ext.	87	60	71	57	45	80	40
	Legs more active than arms	50	80	71	85	63	40	60
Non-crying	Legs mostly bilateral	75%	60%	71%	71%	100%	65%	100%
	Legs ext. more than fl.	75	40	85	71	72	100	80
	Legs extend upward	75	60	42	0	54	60	80
	Arms more active than legs	25	80	56	63	63	40	20
	Tonic neck reflex	50	40	14	28	18	0	80

distinguish crying from non-crying. The marked flexor character of crying behavior may have a protective significance.

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   (For illustrations of facial expression in the crying behavior of the present subjects see the following pages:
   Girl *A*: pages 559, 567, 605, 611, 613, 615.
   Girl *B*. pages 699, 715, 717.
   Boy *A*: pages 861, 889.
   Boy *B*: pages 727, 753, 773.
   Boy *C*: pages 661, 663, 669, 671, 685
   Boy *D*: pages 805, 809, 811, 815, 819, 821, 823, 835.)
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Clinic of Child Development
Yale University
14 Davenport Avenue
New Haven, Connecticut

The Journal of Genetic Psychology, 1941, 59, 249-257.

NON-SEPARATION AS A SOURCE OF DISSIMILARITIES BETWEEN MONOZYGOTIC TWINS: A CASE REPORT*

Department of Psychology, The University of Kansas City

LORENZ MISBACH AND ROLAND N. STROMBERG

The case reported here appears to us to be one in which striking dissimilarities between monozygotic twins reflect dynamic structure of the family field. That structurization of the social field produces dissimilarities of personality in unseparated twins is suggested in various terms and with varying degrees of emphasis in a number of published studies. Newman, Freeman, and Holzinger offer the opinion that conceivably, in cases of nonseparation, ". . . certain preferences in leadership tend to become established, favoring the training of one twin over the other" (6, p. 112). These authors also point out (6, pp. 360-362) that *IQ* and educational achievement are directly related to gross circumstances with reference to which environments of separated twins can be compared, while aspects of development often designated temperament or personality are directly related to subtler environmental factors which are obscured in cases of early separation. Kerr (5) reports evidence, from analysis of results with the Rorschach test, of temperamental dissimilarities between unseparated twins, and offers as interpretation the probability of protest against submergence of individuality, noting that "Twins . . . have so much in common that they might tend to become unlike temperamentally as conscious or unconscious protest." Von Bracken (2), also using the Rorschach test, emphasizes type of mutual relations between twins as the primary condition of development. Divergences interpreted in terms of rôle taking, or preference for leadership, are reported in studies of social development of the Dionne quintuplets (1, pp. 16-17).

Unwarranted dependence upon quantitative scales and weighted selection of cases for psychiatric case-reports (7) have favored underestimation of dissimilarities between unseparated twins. With more analytic methods dissimilarities become more apparent, as in

*Received in the Editorial Office on June 15, 1940

Gottschicks' study of language usage (4) and in studies with the Rorschach test by Kerr, Von Bracken, and Troup (8). Twins reared together are no doubt in general more similar than are twins reared separately, but this is only a general statement of probability which does not signify that in any given case unseparated twins must be more similar than if they had been reared apart. Peculiarly advantageous conditions for studies directed toward description of dynamic properties of environment in relation to social development are offered by cases of extreme or obvious dissimilarity between identical twins reared together. Although interpretations of a single case are inconclusive, investigations of a few cases in each of which dynamic properties of the environmental continuum appear in high relief may yield dependable principles of interpretation permitting comparison of environments with respect to the primary determinants of personality.

To facilitate contrasts, we have used procedures employed by Newman, *et al.* (6), together with additional quantitative methods and greater dependence upon case-history data.

Vital Data and Evidence for Monozygosity

The subjects of this study are twin girls, 11 years and 7 months of age at the time the study was made. They are pleasing, and remarkably similar, in appearance, have no observable anatomic or motor disabilities, and appear to be in good health. Monozygosity is established beyond reasonable doubt by data shown in Table 1.

Developmental History and the Social Field

The twins were full term. Birthweights were: *A,* 5 lbs. 12 oz.; *B,* 8 lbs. There is no exact record of when this difference in weights disappeared, but the parents believe there was no material difference at six months. There were no significant differences in age of walking, nor in attainment of bladder and bowel control.

At six months of age the twins suffered from digestive and pulmonary infection. *A* (the smaller at birth) recovered in a few weeks, but at about the time *A* was recovering, *B* developed pneumonia and was given hospital care for eight weeks. The mother recalls that *B* was convalescent for perhaps an additional two months. In first stages of dentition *A* was nearly two months in advance of *B*. After

TABLE 1
PHYSICAL CHART

	Twin A	Twin B	Degree of similarity
Height	54⅞"	55¾"	
Weight	80 lb.	79 lb 10 oz.	
Head length	10¾"	10¾"	
Head width	9½"	9⅜"	
Cephalic Ind.	.860	.872	
Forehead	7"	7½"	
Hair color	Red	Red	Very similar
Hair texture	Med-fine	Med-fine	" "
Hair whorl	Right	Left	Reversed assymetry
Eye color	Blue	Blue	Very similar
Skin texture	Fine-freckled	Fine-freckled	" "
Handedness	Right	Ambidextrous with right-hand preference*	
Finger prints			Reversed assymetry
Palm pattern			" "
Contour of ears			Very similar
Facial features			" "

*On tapping tests, used by Newman *et al.* (6, p. 42), *A* appears to be ambidextrous. Statements of parents and twins indicate right handedness, with some suggestions of ambidexterity.

the first year there appear to have been no dissimilarities in health, and no severe illnesses occurred.

A is reported to have preceded *B* by about one month in first use of words. This may well have been associated with *B*'s longer illness since both the twins were using definite word-symbols, according to the older sister and parents, at 12 months of age. *B* is said not to have outgrown "baby talk" in pre-school years, and at about six years of age her faulty enunciation began to involve stammering. She has remained linguistically handicapped, her disability now appearing to be primarily slurring or omitting of consonants, with little or no stammering. It may be that she avoids stammering largely by failure or refusal to attempt definite enunciation. In response to questions from persons outside the family, *B* waits for *A* to reply: if this fails, as in the intelligence test situation, *B* falls back on gesture and verbal accompaniment consisting primarily of vowel sounds but for the most part clearly indicating the words required to give brief answers to simple questions. No verbal response of any length was elicited in test situations except in repeating sentences verbatim. *B* exhibits verbal initiative only when the social situation

does not require clear enunciation, and when no embarrassment results from faulty articulation. In family activities, and in play, *B* apparently talks with considerable spontaneity, though still depending largely on *A* to communicate for her.

Throughout reported social development, *A* has been and now is, by far the more aggressive, consistently dominating *B*. The older sister remarked that *"A does all of the thinking for the two."* Some terms used by parents and teachers in describing *A* are "aggressive, dominant, high-strung, self-centered, sociable," while *B* is described as "shy, inhibited, submissive, friendly yet not sociable, a bit apathetic." *A* speaks clearly, and spontaneously. Between the two there apparently exists an intimate coöperative bond, with no evidence of jealousy. Their teacher noted this especially, explaining that they "helped each other out" in all activities, including occasional minor infractions of school regulations, in which *A* is invariably the leader. The twins are in fifth grade work, in a parochial school. While *A* has no difficulty in satisfying school requirements, *B* does have difficulty because of verbal and reading disability. The teacher as well as the parents remarked that *A* covers up *B*'s weakness by doing her reading as well as much of her talking. It is evident that ordinary requirements have been considerably relaxed in the case of *B* so as to keep the twins in the same grade.

It is the general consensus of opinion in the home and neighborhood that *A* is the "smarter" of the two, but that *B* has the "better" personality, being considered quiet and restrained whereas *A* is regarded as being impulsive and self-centered. Both appear to be free to engage in social play activities, and to be liked by neighborhood and school playmates. Although neither of the girls is considered a "behavior problem" by acquaintances, teachers, or parents, it is reported that in the home *A* exhibits rather frequent "temper tantrums," while *B* shows less temper but more "nervousness," reflected in anxiousness or timidity and in occasional somnambulism. In any general clinical comparison *A* would be described as normal and *B* as neurotic.

The father is a mechanic and has been continuously employed since his marriage 17 years ago. The family has been at all times economically secure. Neither of the parents completed elementary school work. The father and mother were 34 and 30 years of age respectively at the time the twins were born. The twins are young-

est in a family of three, the older sibling being a sister, now 15 years of age, in the sophomore year of high school.

The twins are subjected to demands and urgings, especially by the mother and older sister, which are at least with respect to school achievement not consonant with the ability of the twins. It is evident that within the family ambitions and expectations have been in unusual degree projected upon the twins. The older sister has been identified with her parents in this attitude, and has set a pace of scholastic and social achievement which the twins have not the ability to duplicate but which they are expected and urged even to exceed.

Differential treatment of the twins is no doubt related in part to *B*'s early illness and to subsequent consideration of her as the less capable. *A* has, in the family, been cast in the rôle of the "smarter" and more responsible. Insofar as there is or has been any difference in display of affection, *B* has been the more favored. It is probable that this differential treatment is less marked now than it was earlier.

Other than this focussing of ambitions, there is no evidence of any persistent or marked source of disharmony in the family.

Quantitative Study

Scores on tests and other scales are shown in Table 2, with mean differences for separated twins copied, for comparison, from Newman *et al.* (6).

The large difference in reading ability as revealed in the *Stanford Achievement Tests* was confirmed with further tests, including examination with the opthalmograph. *A* excels in all of these tests, her superiority being greatest on those tests emphasizing facility, or the mechanics of reading, rather than comprehension. Telebinocular examination and tests with visual acuity charts revealed no major disability on the part of either *A* or *B*, though *A* was slightly superior to *B* in tests of fusion and in visual acuity.

The Otis *Self-Administering Test* was first used as a measure of general ability, results showing a difference of 15 points *IQ*. But the difference did not appear on the *New Stanford-Binet*. This apparent inconsistency in results was interpreted as reflecting the differential importance of linguistic ability in the two tests. As a further check, the Grace Arthur *Performance Scale* was administered. Results confirm the hypothesis that *B*'s linguistic disability is not a reflection of generally inferior aptitude.

TABLE 2
QUANTITATIVE DATA

		Twin *A*	Twin *B*	Diff.	Mean Diff. for separated twins
New Stanford Achievement					
Reading	E.A.	10-6	7-5	38	
Dictation	"	10-8	8-0	32	
Language Usage	"	8-9	9-3	6	
Literature	"	7-5	9-5	24	
History and Civics	"	7-5	9-1	20	
Geography	"	9-8	7-5	27	
Physiology and Hygiene	"	10-3	7-11	28	
Arithmetic	"	12-2	11-0	14	
Total	"	10-0	8-11	13	16.26
Monroe *Standardized Reading Test*	School Grade				
Words per minute	Equivalent	6	3.7	2.3	
Comprehension	"	4.1	3 3	.8	
Sangren-Woody *Reading Test*	"	4.7	2.5	2.2	
Opthalmographic Tests					
Fixations per 100 wds.	% of Norm	83	109	26	
Regressions " " "	"	104	144	40	
Words per minute	"	117	56	61	
Comprehension	"	80	60	20	
Otis *S.-A.*					
Score		22	7	15	
IQ		87	72	15	8
% Right		34.4	13.5	20 9	14.36
Stanford-Binet					
MA		9-10	10-2	4	15.42
IQ		87	90	3	8.21
Grace Arthur *Performance Scale*					
MA		9-6	10-3½	9½	
IQ		82	89	7	
Downey *Will-Temperament*					
Total Score		36	39	3	9.16
Ave. of diff. on parts of test				.89	1.98
Woodworth-Mathews *Personal Data Sheet*					
No. Neurotic Traits		11	21	10	5
Pressey *X-O*					
Total crossed out		147	109	38	47.16
Deviations		50	57	7	4.89
Kent-Rosanoff *Free Ass'n Test*					
Number common responses		76	70	6	9.63
Average Frequency		88.9	70.6	18.3	39.42
Number Identical Responses		17			14.4

Differences in scores on personality scales are in direction for the most part harmonious with observation and case-history data, but in extent do not, in our opinion, adequately represent the true dissimilarity between the subjects.

Profiles of the Downey test show both subjects scoring above eight points in resistance to opposition and in finality of judgment, at about the median range in reaction to contradiction, and below four in all other parts of the test, both scoring zero on flexibility. Difference in no test exceeds two points. *A* is higher in motor impulsion and lower than *B* in freedom from load and in reaction to contradiction.

On the Pressey *X-O* *A* made the larger number of responses but *B* made a slightly larger number of uncommon responses, thus showing a much larger proportion of unconventional responses. The difference in total number of responses occurs primarily in things thought wrong, where *A* crossed out 61 items, 23 being uncommon, while *B* crossed out 23 items of which 19 are uncommon.

On the Kent-Rosanoff scale, as on the Pressey *X-O*, *A* has the larger total score and the smaller number of uncommon responses.

A's score of 11 unfavorable responses on the Woodworth-Matthews *Scale* is in view of her age somewhat indicative of emotional imbalance, while *B*'s score of 21 is unusually high. *B*'s responses reveal pronounced attitudes of suspicion and inferiority which are not indicated in *A*'s record. Only these unfavorable responses were identical for both subjects.

Interpretation and Summary

It is highly significant that the speech disability exhibited by *Twin B* is associated with a genuine reading disability, and that this linguistic handicap is not reflected in scores on non-linguistic tests of general aptitude. *B* was, presumably, initially retarded by circumstances directly related to her early illness. But this initial retardation cannot in itself account for the large difference now existing between the sisters unless it be supposed that *B* is in some fundamental manner physiologically handicapped, as a result of illness. This possibility we have rejected, since there is no positive evidence for it and since it is not in harmony with the specificity of *B*'s handicap in ability. The clue to this developmental problem seems to us to be the dominance of *A*, and *B*'s dependence upon her. *B* has been, in the family situation, consistently regarded as inferior

in capability to *A*. At the same time the twins, as a dual unit, have been compared with their more capable older sister, and have been urged to meet standards established by her.

Dissimilarity in personality is, we believe, profound. *A* overcomes blockages realistically, while *B* responds at a level of reality so much lower as to be describable as neurotic. It is probable that this neurotic pattern, involving awareness of inferiority, has become more definite as social experiences have increased in range and significance so as to make it more difficult for *B* to maintain identification with her twin.

In terms of non-metricized field-theoretical concepts (3, p. 55 ff.), the region occupied by the twins is highly impermeable and characterized by high potency of membership-character. This region is a focus of tensions directed toward goals, defined for the twins, attainment of which is blocked by limitations of ability on the part of the twins. From their mutual relation, and from experience outside the family, the twins define for themselves goals from which they are blocked by barriers deriving from objectives imposed by other members of the family. The region occupied by the twins is related dynamically to the family field in a manner analogous to the relation of a family to community when the family is subjected to pressure and blockage from without. Brown points out (3, p. 224) that where the family is the focus of this dynamic situation, as in pioneer circumstances, resulting field structure of the family is reflected in definite hierarchy of dominance within the family. The probability of this structurization may be directly related to the number of individuals occupying the region under pressure and to differences between these individuals in age, sex, and related capabilities. If so, the case reported here is exceptional in degree, thus illustrating with unusual obviousness dynamic properties of the social field which in many, or perhaps in all cases, produce divergences in development of twins as well as between siblings reared together.

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Department of Psychology
The University of Kansas City
Kansas City, Missouri

The Journal of Genetic Psychology, 1941, 59, 259-330.

VARIATIONS IN PULSE AND RESPIRATION DURING DIFFERENT PHASES OF INFANT BEHAVIOR*

Clinic of Child Development, Yale University

H. M. HALVERSON

A. INTRODUCTION

There are significant physiological changes from infancy to maturity. Especially noteworthy is the reduction with age in pulse and breathing rates. There is little precise knowledge of the variations of pulse and respiration which are associated with infant behavior.

The purpose of this study was to obtain simultaneous records of pulse and respiratory rates of young infants in situations which normally arise in their daily life, to observe the types of breathing, and to correlate these data with records of the number and nature of the head, hand, and leg movements which occur in the different situations.

B. APPARATUS

Costal and abdominal respiration, pulse, and arm and leg movements were recorded kymographically.

Respiratory responses were recorded by two very light and sensitive pneumographs which communicated with recording tambours. Each pneumograph consisted of a flat toy balloon, inflated size 3.5 x 2.5 x 1.25 inches, enclosed in a tight fitting bag of *ABC* silk. An elastic band, 2 in. wide, drawn through guide straps over the bag, encircled the infant's body. The balloon communicated with the recording tambour by means of rubber tubing 3/16 inch, inside diameter. A glass T-tube, midway of the tubing, permitted inflation of the balloon to the required pressure (2 cm. H_2O). The costal pneumograph encircled the trunk at the level of the nipples, with the balloon midway of them; whereas the abdominal pneumograph passed immediately over the umbilicus. Two adjustable, well-padded strips of stiff rubber, one at each side of the infant, to which the

*Accepted for publication by Arnold Gesell of the Editorial Board, and received in the Editorial Office on June 27, 1940.

encircling bands were attached, served to hold the pneumograph in place. Inspiration deflated the balloons and caused the recording tambours to describe an upstroke on the kymograph paper. Expiratory movements were represented by downstrokes.

The pulse was obtained from the fontanel by means of a specially constructed aluminum tambour which also communicated with a recording tambour by a 3/16 inch rubber tube. The fontanel tambour was of two parts. The base consisted of a disk mounted on four padded legs 90° apart. A circular hole in the center of the disk extended upward through a collar, ⅝ inch in diameter and ¼ inch high. The second part of the tambour consisted of the capsule carrying a latex diaphragm 1⅜ inch in diameter at the center of which was attached a small aluminum disk and post. The neck of the capsule could be adjusted up or down within the collar to the desired height by a set screw. When the tambour was in place the legs of the base rested against the head about the fontanel with the small disk of the diaphragm pressing lightly against the fontanel. Various methods of attaching the fontanel tambour were tried and discarded. For example, Canestrini's arrangement of binding the tambour to the head by elastic bands appeared very definitely to annoy the infant. In addition, even slight movements of the head displaced the tambour. Best results were obtained by having the assistant who sat at the right of the crib hold the tambour against the head.

Arm and leg movements were also recorded pneumatically. A small rubber capsule, 2⅝ inches long and ⅜ inch in diameter, was placed on the back of the hand. The capsule was enclosed in a close-fitting satin sheath at one end of which was attached a cloth pocket which fitted over the ends of the third and fourth fingers. The sheath terminated at the wrist where it was held in place by an encircling elastic band. When the apparatus was placed on the fully extended hand the slightest movements of the fingers or hand were recorded. Flexion of the hand compressed the capsule and produced an upstroke of the stylus of the recording tambour. Extension of the hand caused the stylus to move downward. Extension and flexion of the leg were recorded in similar manner by placing a small flat rubber balloon just above the knee and encircling the leg and balloon at this point with a broad elastic band. The stretching and relaxing of the band produced changes of pressure within the balloon which were communicated to the

recording tambour. Flexion of the leg was recorded by an upstroke of the recording stylus and extension by a downstroke.

An extension kymograph carrying a paper 10 inches wide, time marker, and signal marker, completed the apparatus. All tambours were equipped with sensitive corrugated latex diaphragms. The latency in recording by the transmitting tubes, each less than 10 feet in length, was negligible. The lightness and flexibility of the apparatus attached to the infant permitted complete freedom of movement. There were no indications of discomfort. His behavior apparently was in nowise different than that in his own crib.

C. Subjects

The experiment was conducted at the State Farm for Women at Niantic, Connecticut. Eighteen boys and 25 girls, ranging in age from 2 to 24 weeks, served once each as subjects. All infants were in sound physical condition and of normal gestation period. Due to differences in behavior during the experimental period and the fact that no infant is represented more than once in each situation, the number of infants in the different situations varied considerably.

D. Procedure

The infant was undressed in the nursery, covered with a blanket, and carried to the observation room just before the morning feeding period at nine o'clock. The blanket was then removed and the infant placed in the experimental crib. After the apparatus was carefully attached, the infant was given his bottle. The temperature of the room varied from 83° to 88° F. The experimental period ended in time for the noon feeding at one o'clock.

Records were obtained in 18 situations, four of which for reasons given later were listed as supplementary. Each record, unless otherwise specified, was two minutes long. The situations and conditions under which the records were taken were as follows:

1. *Nursing*, after five minutes of feeding.

2. *Satiation-Quiet*, within five minutes after the end of feeding.

3. *Satiation-Animated*, within five minutes after the end of feeding. The infant was "feeling good" as in Pleasurable Activity (see below).

4. *Satiation-Going to Sleep,* within 10 minutes after the end of feeding, immediately after the first closing of the eyes.

5. *Going to Sleep,* at any time. (Includes all cases of Going to Sleep.)

6. *Early Sleep,* after 5-10 minutes of undisturbed sleep.

7. *Profound Sleep,* after 30 minutes of undisturbed sleep, when two successive loud hand claps, administered three feet from the infant's head, failed to alter the breathing pattern.

8. *Sleep before Awakening,* opportunistically when observations indicated the infant was about to awaken.

9. *Pleasurable Activity,* after awakening when the infant was "feeling good."

10. *Quiescence,* whenever the infant was quietly watching the assistant.

11. *Restlessness,* at any time when the infant, otherwise quiet, moved about restlessly without any overt demonstrations of emotional excitement.

12. *Fretting,* at any time the infant indicated unpleasant emotional excitement short of crying.

13. *Crying,* at any time.

14. *Quieting after Crying.* The records include only those cases in which there was no further crying.

Supplementary situations

15. *Quiet Awakening,* opportunistically. The record covers the transition from sleep to waking in instances wherein there were no indications of emotional excitement.

16. *Micturition,* opportunistically.

17. *Defecation,* opportunistically.

18. *Hiccoughs,* opportunistically.

E. Technique for Analysis of the Records

Table 1 lists 14 of the situations with the number and age of the subjects who participated in each one. The table also indicates for each situation the mean, median, and range measures of the data obtained from the kymographic records pertaining to pulse, respiration, and movements of the head, hand, and leg.

All details concerning the pulse were obtained from the pulse curve. The data procured from the breathing curves were supplemented by visual observations of the movements of the chest and abdomen. Limb movements were likewise observed.

As a rule little difficulty was experienced in obtaining pulse rates. In most of the situations the pulse beats were counted for a con-

Table I

Pulse Rate, Breathing Rate, Measures of Various Aspects of the Breathing Curves, and the Number of Hand, Leg, and Head Movements per Minute in the Different Situations

Situation	Number of Cases		Age in Weeks	Pulse Rate per Minute	Respiration Rate per Minute	Costal Movements of Respiration: Amplitude of Individual Respiratory Movements, Mean	Costal: Amplitude, Minim.	Costal: Amplitude, Maxim.	Costal: Extreme Height of Curve (mm.)	Costal: Height of Highest Trough (mm.)	Costal: Number Troughs out of Alignment per Minute	Costal: Number Undulations per Minute	Abdominal Movements of Respiration: Amplitude of Individual Respiratory Movement, Mean	Abdominal: Amplitude, Minim.	Abdominal: Amplitude, Maxim.	Abdominal: Extreme Height of Curve (mm.)	Abdominal: Height of Highest Trough (mm.)	Abdominal: Number Troughs out of Alignment per Minute	Abdominal: Number Undulations per Minute	Number Hand Movements per Minute	Number Leg Movements per Minute	Number Head Movements per Minute
Crying	35	Mean	9.6	179.3	133.3		0.5	7.9	31.6	25.4	42.2	25.9		0.5	9.7	39.6	29.2	33.1	20.1	75.7	70.7	78.8
		Median	9	179.	134.		0.5	6	31.	24.	38.	25.		0.5	8	40	31.	34.	20.	74.	74.	80.
		Range	2-22	136-220	97-176		0	2-21	13-58	9-52	20-84	10-52		0	2-29	14-69	7-59	20-59	10-41	17-165	18-127	22-141
Satiation-Animated	21	Mean	13.3	152.7	99.5	2.5	0.6	8	28.8	22.4	25.9	17.4	3	0.6	11.1	28.7	20.5	24.7	21.4	46.7	58.3	35.3
		Median	12.	153.	100.	2	0.5	6	26.	18.	26.	16.	3	0.5	8.	26.	20.	26.	20.	41.	63.	35.
		Range	5-24	135-170	74-122	1-5	0.5-1	4-21	10-50	8-44	12-37	4-45	1-5	0.5-1	3-51	10-72	7-57	18-32	4-42	20-102	24-92	13-58
Fretting	28	Mean	9.6	155.	97.9		0.9	10.9	27.8	20.7	22.6	11.8		0.9	14.3	35.9	26.1	20.7	11	52.4	54.9	34.5
		Median	8	156	99		0.5	10.5	28	20.5	28.5	10.5		1	13.5	35.	27.	19.5	10	45	49.5	34
		Range	2-22	141-172	66-146		0.5-3	3-24	11-59	7-52	14-42	4-22		0.5-2	4-28	16-59	9-48	10-36	4-25	23-128	31-102	17-50
Pleasurable Activity	18	Mean	15.8	150.4	91.7	3.6	0.6	9.2	25.5	19.5	21.1	18.4	3.6	0.8	11	32.6	24.6	19.6	17.5	42.7	57.7	26.8
		Median	16	149.1	97.5	4	0.5	7.	24.	18.	21.	18.	4	1	10.5	34	26	19.5	18	40	52	28.5
		Range	5-24	132-168	70-100	1-6	0.5-1	3-20	13-60	8-50	12-31	5-33	1-8	0.5-1	4-21	10-50	8-44	12-26	9-37	18-76	40-89	9-46
Restlessness	12	Mean	11.1	144.3	84.2	2.6	0.9	7.3	22.	17.3	21.5	13.1	3.5	1.1	12.1	27.2	19.0	18.8	13.2	32.7	29.0	22.9
		Median	9	142.	85.	2.	1.	6.	20.	16.5	20.	8.5	3.5	1	9.5	28	18.5	19	8.5	32	34.5	18.5
		Range	5-22	135-158	70-106	2-4	0.5-2	3-14	10-37	7-30	14-35	5-35	2-6	0.5-3	4-24	10-56	6-39	10-30	6-30	16-52	7-56	11-56
Quieting after crying	9	Mean	9.6	148.3	83.1	3	1	6.6	13.4	9.6	19.7	5.7	3.2	1	8.1	18.2	14.3	16.7	5.6	18.4	24.1	11.8
		Median	8	146.	87	3	1	6	13	10	18	5	3	1	7	12	8	14	5.	17	19	12
		Range	4-17	132-176	62-112	2-5	0.5-2	4-11	7-21	3-14	13-28	3-12	2-6	0.5-2	4-21	7-54	4-48	9-26	3-10	1-60	1-56	1-24
Satiation-Quiet	19	Mean	11.5	146.5	73.9	2.8	1.7	5.7	14.9	10.8	16.2	5.1	6.1	2.5	9.5	21.9	15.8	15.1	5.8	12.5	19.5	12.6
		Median	11	143	74	2	1	4	13	11	16	5	6	2	8	19	12	16	6	8	16	11
		Range	2-24	136-164	50-104	2-6	0.5-4	3-23	5-26	3-23	7-24	2-12	2-10	1-4	6-22	10-60	5-59	7-26	2-9	0-37	0-50	0-36
Nursing	8	Mean	17.8	151.8	51.6	5	2.4	8.8	17	12.4	14.8	7.3	5.6	3	8.9	15.2	8.9	14.9	5.8	7.9	6.3	2.3
		Median	19.5	150	51.5	3.5	1	8	16	9	15.5	4.5	6	3	9.5	12.5	6	14.5	5	6	5	0
		Range	7-24	134-168	40-67	2-10	1-7	4-14	7-31	5-28	11-18	3-17	3-7	1-5	4-13	7-34	4-17	5-20	3-11	0-23	0-20	0-11
Satiation-Going to Sleep	8	Mean	10.8	140.	50.9	2.8	1	5.4	11	7.9	5.6	5.9	6.1	2	8.1	13.3	7.3	6.3	3.8	3.6	6.5	3.9
		Median	8.5	140	48	3	1	5	9	5	4	5	6	2	8.5	13	3	7	4	2.5	2	3.5
		Range	5-22	123-152	43-67	2-4	1-2	4-8	6-22	3-18	4-11	4-11	3-8	1-4	4-11	9-20	3-17	3-10	1-6	0-10	0-33	0-12
Quiescence	10	Mean	10.1	133.2	64.2	2.6	1.5	4.7	8	4.5	11.0	4.6	3.7	1.5	6.4	9.1	5.2	9.7	4.2	4.8	5.1	1.4
		Median	9	133	70	2.5	1	4	7.5	4.5	9	5.5	4	1	7.5	8.5	5.5	9	4	4.5	4.5	0
		Range	3-22	119-144	47-76	1-6	0.5-4	3-9	5-12	2-8	7-18	3-8	1-7	1-3	3-11	4-15	2-10	3-20	2-8	2-12	2-10	0-5
Sleep before awakening	6	Mean	18.2	123.2	32.3	3.2	1.7	8.3	10.3	6.6	5.3	2.5	7.5	4	11.7	16.5	6.3	4.2	2.2	5.3	3.8	2.5
		Median	19.5	125.5	30.5	3	2	4	6	2	5.5	2.5	8	4	11	14.5	4	5	2.5	3	3	1.5
		Range	9-22	109-138	25-47	3-4	1-2	3-30	4-35	1-29	1-8	1-4	6-8	1-7	7-17	18-33	0-16	1-6	0-3	0-18	0-9	0-8
Going to sleep (All cases)	23	Mean	9.1	132.9	47.7	3.2	1.4	5.6	9.9	6.3	5.7	5	6	2.8	8.7	12.4	5.9	5.3	3.7	2.1	3.5	1.7
		Median	7	132	45	3	1	5	8	5	4	4	6	3	9	12	5	5	3	1	1	1
		Range	2-24	117-152	34-67	2-6	0.5-4	4-8	5-22	1-18	2-11	2-11	3-8	1-5	4-15	7-20	2-17	2-10	1-6	0-10	0-33	0-12
Early Sleep	41	Mean	9.5	129.3	42.5	3.2	1.7	5.1	7	3.7	2.6	3.7	6.6	3.4	10	11.9	4.7	5.4	3.3	1.2	1.3	1
		Median	6	129	42	3	2	5	6	3	6	3	6	3	9	12	4	5	3	1	0	0
		Range	2-24	114-154	28-66	2-6	1-4	3-11	4-12	0-8	2-14	0-7	4-10	0-8	4-20	6-23	1-11	1-11	0-8	0-9	0-9	0-6
Profound Sleep	31	Mean	11.8	123.5	33.9	3.3	2.6	4.2	4.8	1.5	3.2	1.2	6.9	4.9	8.7	9.5	1.7	3	1	0.1	0.03	0.1
		Median	8	125	35	3	3	4	5	1	2	1	7	5	8	9	1	2	1	0	0	0
		Range	2-24	106-138	19-44	3-5	2-4	3-8	3-8	0-5	0-8	0-3	5-10	1-8	6-17	7-17	0-5	0-8	0-3	0-2	0-1	0-3

tinuous run of a full minute. The excitement attending *Pleasurable Activity* and *Satiation-Animated* occasionally reached a height which for varying intervals precluded accurate estimation of the rate. However, there were sufficient less-disturbed portions of the pulse curve to provide a full minute's count. Catching the pulse at these intervals means, of course, that the recorded rate is probably somewhat lower than the actual rate.

The greatest difficulty was encountered in determining pulse rates for Fretting and Crying. The pulse was not only very irregular but its amplitude was greatly reduced during periods of intense excitement. Accurate recording of high pulse rates is in itself a difficult procedure (21, 60). The beats are clearly delineated only for short intervals of relative quiet, such as holding the breath, long smooth or extended expiration, pauses after deep exhalation, and momentary cessation of bodily activity. Hence, inasmuch as the number of such intervals occurring within a two-minute period was insufficient for adequate determination of the rate, the records of *Fretting* and *Crying* were extended to cover a period of four minutes. The number of intervals in which pulse beats were clearly represented on the curve was now sufficient to provide cumulatively for each of 35 infants at least 15-30 seconds of pulse beats. The total number of these beats, calculated in terms of a full minute, was regarded as the mean pulse rate. Maximum and minimum rates were obtained from the highest and lowest rates of the individual intervals.

The method employed in obtaining measurements of the breathing curves was rather complicated. Inasmuch as the differences between the breathing patterns were due to alterations in both depth and rate of respiration, certain common components of the breathing curves were measured in accordance with pre-established standards. The items listed at the top of Table 1, under *Costal and Abdominal Movements of Respiration*, indicate which features of the curves were measured. Only the central tendencies and the dispersion of the measures are presented.

Measurements were made by means of a transparent ruler with a millimeter scale. The amplitude of respiratory movements less than 1 mm. was recorded as one-half mm. The amplitude of a respiratory wave is the vertical distance from its peak to a line joining the troughs of the waves. The mean amplitude of the respiratory movements in each situation was obtained from the measures

of the individual waves of a 30-second interval of breathing which was fairly representative of the infant's breathing during that situation. Minimum and maximum amplitudes indicate the magnitudes of the smallest and the largest respiratory movements. The extreme height of the curve is the distance from the top-most portion to the base line, viz., the horizontal line joining the lowest troughs of the curve. The height of the highest trough is also measured from this line. The number of troughs out of alignment with the general line of the troughs and the number of undulations per minute are other items indicative of the character of the breathing. The one refers to occasional abrupt changes in the expiratory position of the chest or abdomen caused usually by a single abbreviated or exaggerated expiratory movement. The other refers to the gradual and more extensive alterations in the expiratory position.

Undulations in the breathing curve occur in all situations, except occasionally in profound sleep. The more quiescent and relaxed the infant, the longer, lower, and more gentle the undulations. The greater the activity or the excitement, the higher, more rugged, and in most cases, the shorter the undulations. In fact, in exciting situations, the tortuous bendings of the curve in no way resemble undulations in the strict sense of the term, but for classificatory purposes are regarded as such. It is not uncommon to find several minor undulations within a larger one, an arrangement which signifies that a series of climaxes occurred during a wave of excitement. Undulations were classified as such only when they included four or more respirations; the smaller ones were placed in the category, *troughs out of alignment.*

F. Respiration in Infancy

Comparison of the breathing curves reveals distinctive features other than differences in respiratory rate which differentiate the breathing in the various situations. In short, the breathing mechanism responds immediately in very definite ways to changes in behavior. These responses are represented on the curves by characteristic breathing patterns. The patterns are relatively simple during sleep and increase in complexity with muscular activity and emotional excitement. It would be well, therefore, to review briefly some of the facts concerning infant respiration and to note the character of the breathing in the different situations in this study.

The child *in utero* receives its oxygen and discharges its carbon

dioxide through the placenta. Although the lungs at this time contain no air, Snyder and Rosenfeld (52) state that spontaneous respiratory movements of several minutes' duration occur in the human fetus. According to Bonar, Blumenfeld, and Fenning (4) these movements indicate the probability of a rhythmic flow of amniotic fluid in the air passages of the lungs. Ahlfeld, cited by Feldman (15) observed rhythmic but irregular intra-uterine movements of the fetus which varied in number from 38 to 76 per minute and attributed them to contractions of the respiratory muscles. He assumed that the purpose of these movements was to strengthen the diaphragm and thoracic muscles for use after birth. Hence, while air breathing occurs only after birth, the respiratory movements are initiated during fetal life.

Although the lungs of the neonate are relatively small, their growth is so rapid that at three months their weight is about double that at birth (15, 48). At 11 months the volume of the lungs is about four times that at birth (15). As an indication of the rapid development of the lungs Gregor (24) points to the unusual increase in the amount of residual air in quiet breathing during the first year. Hagemann (28) states that inasmuch as the rôle of the upper lobes in breathing is relatively insignificant in early infancy, costal respiration is of little consequence until near the end of the first year. In this connection Feldman (15) calls attention to three peculiarities of structure of the thorax of infants which account for the predominance of abdominal breathing in early life. The thorax of the newborn infant is generally somewhat conical in form with its smaller circumference at the level of the arm pits, whereas the thorax of the adult is more barrel-like in shape. It is believed that the transformation in shape occurs at about the third or fourth years. Secondly, the antero-posterior diameter is equal to, or even greater than, the transverse diameter. The latter diameter, however, increases at a more rapid rate throughout childhood and at puberty is double its birth size. Thirdly, the position of the ribs in infancy differs from that in adulthood. At birth they extend almost at right angles with the spinal vertebrae. With age they gradually sink at the lateral aspect of the thorax until in the adult stage their obliquity is quite pronounced.

The chest cavity may be expanded to produce inspiration by contraction of the diaphragm and by elevation of the ribs. Expansion of the diaphragm and depression of the ribs contracts the thorax

and produces expiration. There are two main types of respiration—the abdominal and the costal types (36). In the abdominal type the abdomen expands first and this is followed by the elevation of the ribs. In the costal type the upper ribs expand first and the movement spreads from the thorax to the abdomen. In quiet breathing expiration quickly follows inspiration. Expiration usually starts rapidly, ends slowly, and is frequently followed by a momentary pause before the next inspiration takes place.

Gregor's photographs of the contour of the body during inspiration and expiration (24) show that breathing in infancy is of the diaphragmatic type. This is due to horizontal postuie and the weakness of the bones and muscles of the thorax. As a result of intestinal pressure against the lungs, breathing is shallow, hence adequate ventilation can be provided only by an increase in the frequency of respiration. When the child first assumes the erect posture the consequent sinking of the abdominal organs and anterior thoracic wall and the greater downward slope of ribs conduce to deeper breathing. Elevation of the ribs in breathing movements increases with the gradual strengthening of the muscles of the thorax. The chest expands transversely and antero-posteriorly as its movements become larger and assume the characteristics of adult movements in what Gregor terms abdomino-thoracic breathing. After the third year breathing is of the thoracic type, and at 10 years it is abdomino-thoracic in males and thoracic in females.

According to Gundobin, cited by Feldman (15), breathing is more irregular and superficial in children than in adults. The rapid rate of respiration in infancy is due to a "hindering action of the diaphragm" in the recumbent position. Deming and Washburn (12) studied respiration in 27 normal infants, ranging in age from birth to 13 weeks. They observed variations in the breathing of nearly all of the infants. In many cases two or more types of breathing, as well as fluctuations in rate and volume, were demonstrated in a single record. Records taken when the subjects were quietly awake failed to disclose distinct types of breathing. The rate of respiration was more rapid than during sleep and the breathing more variable in both rate and volume. Samples of breathing during sleep revealed three principal types of respiration: (*a*) Regular, in which the duration of inspiration and expiration were about equal with no pronounced pause between breaths. The rate was uniform and rapid. (*b*) Slow type, in which a quick inspiration

was followed by a prolonged expiration of cog-wheel character. The rate was quite uniform but lower than in the first type. The depth of inspiration was either constant or variable. (*c*) Periodic. The amplitude of inspiration waxed and waned in recurring cycles. In the extreme type the breathing was of the Cheyne-Stokes order. In the moderate type the apneic interval was absent. There were minor and major variations in rate and amplitude of respiration.

Hutchinson (36) describes two types of pathological respiratory movements which at times occurred in the present study. The first type, double breathing (unisonal), wherein the movements of diaphragm and thorax were synchronized, was frequently observed in this study during periods of excitement, viz., during play, fretting, and crying, and on two occasions during sleep. The second type, reversed breathing movements, wherein breathing was costal at one time and abdominal at another, also occurred under the above conditions and was especially marked at the start and end of an exciting period. A third type, antagonistic respiratory movements, not mentioned by Hutchinson, occurred during excitement and also during nursing. Breathing in this case is entirely costal. On inspiration the thorax expands while the abdomen sharply contracts. The antagonistic action of the abdomen serves to increase the volume of the thorax and thus, instead of interfering with inflation of the lungs, actually aids costal inspiration. On expiration the abdominal muscles relax to permit the thorax to collapse and deflate the lungs.

The sequence of the respiratory movements of thorax and abdomen during periods of strong excitement defies accurate description. Breathing becomes disorganized. The numerous alterations from one type of respiration to another, the rapidity and irregularity of the changes, the shift of an inspiratory or expiratory movement from abdomen to thorax or vice versa, abrupt stops, marked differences in amplitude of successive inspirations and expirations, and temporary suspension of movement by either abdomen or thorax, or both, attest to the disorderly action of the respiratory mechanism.

The present study appears to indicate that respiratory patterns differ among individuals and to a great extent serve to identify them. No two of our breathing records were identical, even when the infants were asleep. Differences between infants were observed in the rate and amplitude of the respirations, in the length and height of undulations, and in the time elapsing between inspiratory movements of abdomen and thorax. In this connection Sutherland, Wolf,

and Kennedy (56) reported that each of their nervous patients showed a respiratory "personality," a "finger print" which was quite identifiable. Neilson and Roth (42) found nine types of respiration in people and came to the conclusion that some of the types were hereditary.

G. Character of the Breathing in the Different Situations

1. *Quiescence*

Infants are only relatively quiet for short periods during waking, except when they are sleepy or satiated. In other words, waking is a time for action. On occasion they may lie quietly for several minutes as they regard some object of interest (as the experimenter). Breathing during these intervals is to a certain extent affected by their previous activity and is likely to be somewhat rapid and irregular. Constant alteration of the expiratory position of chest and abdomen causes the breathing curves to assume a very undulatory course. The undulations are similar to, but are somewhat more abrupt than, those shown in Figure 2, Type 3, *A* 1, and the respiratory movements (Figure 1, Type 1, *A*, Hill and Dale) are irregular

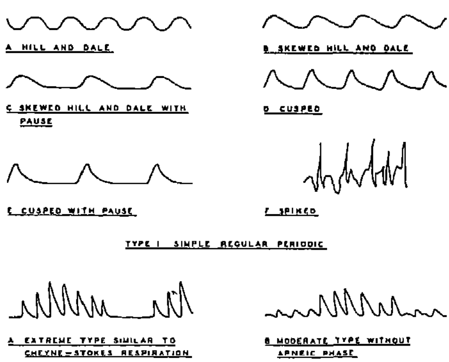

FIGURE 1
Types of Breathing Curves (Without Undulations)

in depth and duration. Slow, small movements of the hands and legs occur intermittently, but the movements of the legs are the more conspicuous.

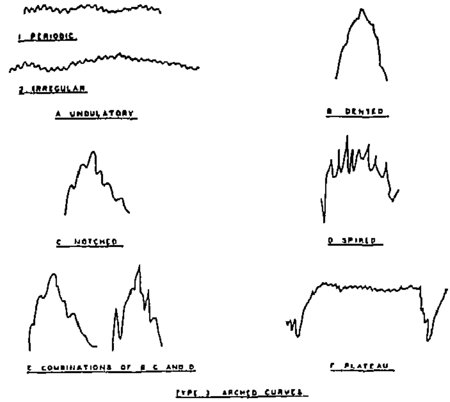

FIGURE 2
TYPES OF UNDULATORY BREATHING CURVES

2. *Nursing*

Breathing during contented nursing is quite regular but slower than in other waking situations, even when the infant is quiet. The amplitude of the abdominal movements and the undulations in the abdominal curve are about the same as during quiescence, whereas the amplitude of the costal movements is greater and the undulations gentler but higher. Thus the infant compensates for the reduction in the rate of breathing by an increase in the amplitude of the costal movements. The burden of so effecting an increase in the depth of breathing accounts for the more abrupt alterations in the expiratory position of the chest. The curve resembles that of Figure 2, Type 3, *A* 2, but is frequently higher. The respiratory waves are either Hill and Dale or Skewed Hill and Dale (Figure 1, Type 1, *A* and *B*). The movements of thorax and abdomen are usually in opposition, i.e., the chest expands as the abdomen contracts and vice versa.

During strong, steady sucking the infant clenches the hands and raises the legs with the knees sharply flexed. Muscular tension generally is fairly constant until near the end of the feeding period when movements become frequent.

3. *Satiation-Quiet*

Respiration is usually rapid, only three of the 19 infants having a breathing rate below 60 respirations per minute. The breathing

curves are of the irregular undulatory type (Figure 2, Type 3, *A* 2) but are somewhat higher and generally much more abrupt. The respiratory movements are of the shallow Hill and Dale type with inspiration and expiration of about equal duration. The abdominal movements are slightly larger than the costal movements. In some cases there are alternate periods of very regular breathing and irregular breathing. In other cases respiration is irregular throughout, particularly in depth. Breathing is further complicated by sighs and deep, protracted expirations, and also by an occasional deep inflation, extending over a period of several seconds, during which respiration goes on as usual. The curves on the latter occasions resembled the Notched type (Figure 2, Type 3, *C*). Breathing is of the abdominal type.

The number of head, hand, and leg movements varies considerably. Some infants lie very quietly, some move only at intervals, and some are in almost constant movement. With few exceptions all activity is carried on leisurely and smoothly. Leg movements are more frequent than either head or hand movements and of relatively greater scope.

4. *Satiation-Animated*

After nursing the infant may go to sleep, lie quietly awake, fret, cry, or engage in playful activity. There are, of course, degrees of excitement during play. The infant may move about quietly, smiling and vocalizing; or he may be highly animated so that he rocks, rolls, kicks, arches his back, and utters little squeals. During great excitement breathing is of the costal type. Respiration is in general shallow, audible, and very rapid and irregular. At times the movements of abdomen and thorax are quite in unison and at other times in direct opposition. The volume of air in the lungs fluctuates rapidly. Partial inspirations and expirations, catches in breath, and rapid alterations in the amplitude and duration of the respirations occur in irregular order with the lungs in varying stages of inflation. The breathing curves pursue a tortuous course without any apparent base. Undulations give way to abrupt arches. The costal curve attains a high altitude, coursing up and down with each wave of excitement, and sinking to a low level when excitement subsides. The height of the curve varies directly with the degree of the excitement. The abdominal curve describes a more erratic course, rising suddenly to great heights and as quickly descending to a very low

point. When excitement runs high the respiratory movements of the two curves are antagonistic. Each downward plunge of the abdominal curve is accompanied by a rise in the costal curve. As the excitement subsides breathing becomes unisonal. The arches of the two curves usually rise simultaneously but from then on are as frequently out of phase as in phase.

The breathing pattern for mild excitement with some modifications is similar to that for high excitement. Breathing is somewhat slower and less irregular, but there is the same instability in the amplitude and duration of the respirations. The arches are lower and more undulant in appearance. Although both curves oscillate freely up and down in unison and out of phase, fluctuations in the state of excitement are more clearly represented on the costal curve.

The legs are predominantly flexed at the hips with both feet erected. In the more quiet moments the movements are slow and small. At times both feet are lowered upon the bed pad. At other times one foot is lowered and the other pumped up and down. With increase in excitement the tempo and scope of movements increase. A rapid succession of strong extensor thrusts with the legs moving in unison or alternately in treadmill manner imparts a longitudinal rocking motion to the body. As the excitement subsides the movements again become slower and more confined.

Arm movements are more limited in scope. With mild excitement the hands open and close more jerkily in and out over the chest. As the excitement increases and the chest expands, the number and scope of the movements increase. The arms move farther out laterally and the fingers tend to extend. When the excitement abates, the hands tend to close and move nearer the trunk. The number of arm movements may exceed that of the leg movements when the activity is lively but not too vigorous, but the latter movements are more prominent. There is no coördination between flexion or extension activities of arms and legs.

Movements of the head frequently become so large and numerous that the pulse beats cannot with certainty be distinguished.

Arched curves, similar to those shown in Figure 2, Type 3, *B, C, E,* and *F,* and combinations of them, compose the costal breathing curve. The abdominal curve is perhaps best represented by the arches illustrated in Type 3, *E*. In mild excitement the shallower arches are studded with the Hill and Dale waves of less irregular respirations.

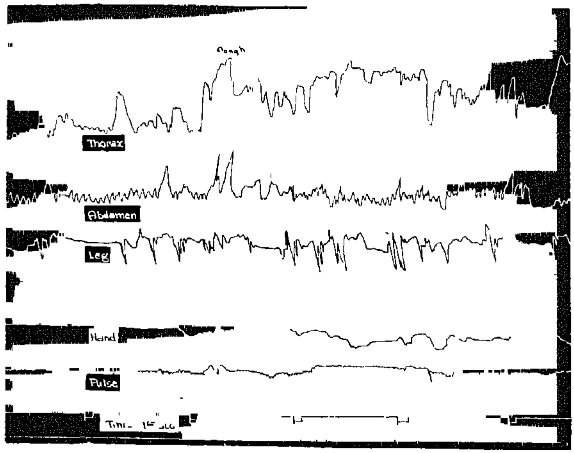

FIGURE 3

SATIATION-ANIMATED

Playful activity, including vocalization, smiling, and kicking. The subject is a girl, 17 weeks old. The costal curve rises as excitement increases and descends as it abates. The greater the excitement the higher the curve. The abdominal curve is relatively low throughout. Respiration is generally fast and shallow. The legs, predominantly flexed, intermittently execute major and minor extensor thrusts. The hands are flexed but tend to extend with increase in excitement The pulse curve rises and the beats become smaller and more diffuse with increase in excitement.

Figure 3 graphically presents the play behavior of a 17 weeks' old girl during pleasurable excitement. Smiling, yawning, coughing, and vocalizing occur during this period. The abdominal curve is relatively more level than the costal curve which shows respiration taking place at varying stages of lung inflation. The height of the curve increases with the degree of excitement. With abatement of excitement the costal curve falls and the respiratory movements tend to become more uniform. The leg curve shows that the legs are predominantly flexed. Major and minor extensor thrusts occur during intervals of strong excitement and small, slow movements during calmer intervals. The fingers, flexed at the start, move relatively less than do the legs, but become active and more extended as play continues. The pulse curve becomes irregular during excitement. The abrupt changes in level are occasioned by sudden head movements, the more gradual changes by increases and decreases in brain

volume. Note that elevations in the curve usually parallel those in the costal curve and that the pulse rate accelerates and the amplitude of the pulse waves diminishes as the brain volume increases.

5. *Pleasurable Activity*

Except for the fact that pulse rates and breathing rates tend to be slightly lower during Pleasurable Activity than during Satiation-Animated, the behavior of the infants is essentially the same in the two situations.

6. *Going to Sleep*

Breathing is always of the abdominal type during sleep. The more profound the sleep, the slower the breathing rate and the greater the interval between the corresponding movements of respiration of abdomen and thorax. The transition from waking to sleep is marked by constant and marked alterations in the expiratory positions of chest and abdomen. The breathing curves weave up and down more or less irregularly both before and after the eyes close. As sleep continues they assume a slower and more uniformly undulating course. The upward course of the curves is occasionally attended by movements of head, hands, or legs, giving the impression that the infant is about to awaken. The downward course is usually more tranquil and very suggestive of a sinking-into-sleep phase. This idea is supported by the fact that the downward course gradually dominates the situation and causes a decline in the base line of the curve. The decline is more conspicuous in the case of the costal curve. The transitional period from waking to sleep may be short or very protracted. The infant may open his eyes several times, startle for no apparent cause, adjust and readjust his limbs and head, or when sucking his thumb, partially awaken when the thumb slips from his mouth.

Breathing is slower than in waking and the abdominal movements are greater and more uniform in amplitude than are the costal movements. Respiration may be very irregular in both rate and depth; it may vary greatly in one of these respects and but little in the other; it may be alternately regular and irregular; or it may be very regular for long intervals. The breathing may be punctuated by an occasional sigh or a deep extended inspiration, followed by an equally deep but more rapid expiration. Cheyne-Stokes breathing of the moderate type and other peculiarities in breathing occasionally

occur at this time. One infant, whose respirations were very regular, suddenly ceased breathing. After a pause of seven seconds respiration continued regularly, without any further interruption.

Costal movements on the kymographic records are represented by plain or Skewed Hill and Dale waves on a markedly undulatory curve; abdominal movements, by Skewed Hill and Dale or Cusped type of wave (Figure 1, Type 1, *D*) on an equally undulatory curve. The limbs are usually extended and motionless except for occasional twitching or relaxing of the fingers.

Figure 4 is the record of a girl of 17 weeks. Note the irregu-

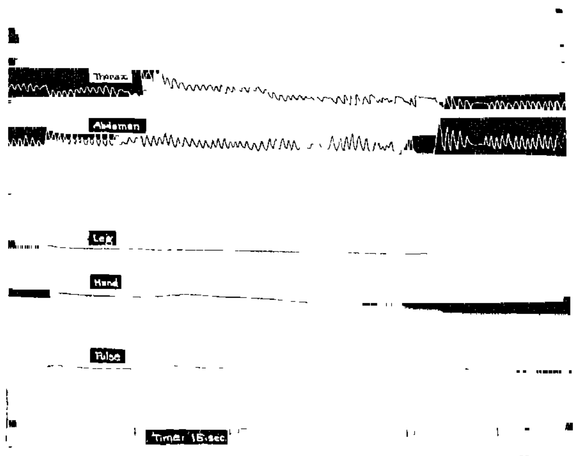

FIGURE 4

GOING TO SLEEP

The subject is a girl, 17 weeks old. Breathing is fairly rapid with no pause between respirations. Note the gradual sinking of the costal curve and the tendency toward Cheyne-Stokes breathing near the end. The legs are relatively quiet but the hand continues to move as it gradually relaxes its grip. The pulse curve is somewhat undulant.

larities in the breathing curve, including the tendency toward Cheyne-Stokes breathing near the end. The leg is relatively quiet, but the hand continues to move as it gradually relaxes its grip. The pulse curve is somewhat undulant. Its sharpest rise coincides with the abrupt rise in the costal curve. As a rule, the undulations in the

pulse curve frequently coincide with those in the costal curve in all situations.

7. *Early Sleep*

Some of the infants went quietly to sleep immediately or soon after feeding; while others remained awake for one or two hours before sleeping occurred. Of the latter, some dropped asleep quietly, others slept only after a period of crying. Only two of the infants were in a state of profound sleep at the time the records were obtained.

The breathing curves during early sleep sinuate up and down, but the undulations are slower, gentler, and of smaller amplitude than those which occur during the period of falling asleep. Respiration is slower than during *Going to Sleep,* but is still unstable. In some cases it is slightly irregular in both rate and depth. In other cases periods of measured respirations are broken by irregular respirations in which alterations in depth are conspicuous. Incomplete expirations, deep inhalations, holding the breath, and momentary quickened breathing further contribute to the instability of respiration. In general, the curves indicate that the costal movements are less variable than are the abdominal movements. Movements of the head and limbs are very infrequent.

Costal respiratory waves are either Skewed Hill and Dale or Skewed Hill and Dale with pause. Abdominal waves are Skewed Hill and Dale, Cusped, or Cusped with pause. Abdominal inspiratory movements are much faster than the expiratory movements. Costal inspiratory movements are relatively slow but somewhat faster than the expiratory movements.

Figure 5 is a typical record of *Early Sleep.* The subject is a boy of 22 weeks.

8. *Profound Sleep*

Breathing is eminently abdominal in type and the amplitude of the abdominal movements is about twice that of the costal movements. Costal movements lag far behind the abdominal movements. In fact, the lag is frequently so great that the costal inspiratory movement does not begin until the abdominal inspiratory movement is completed and the expiratory movement is well on its way.

In general, breathing is very regular and the rate is much lower in Profound Sleep than in any other situation with the exception

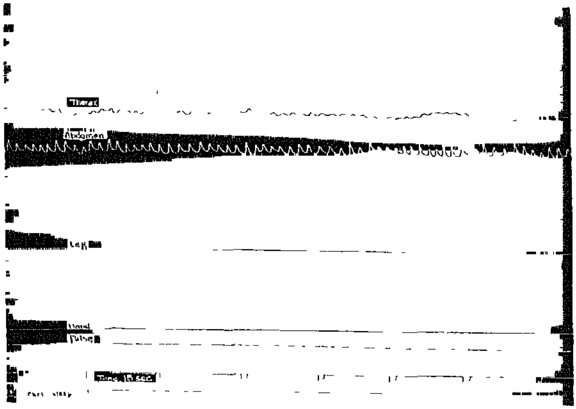

FIGURE 5
EARLY SLEEP
The subject is a boy, 22 weeks old. Breathing is slower than in *Going to Sleep* but is still somewhat irregular, particularly in depth. Instability of breathing is further indicated by the undulations in the breathing curves. The hands and legs are quiet. The pulse is quite steady.

of the period preceding awakening. Stability of breathing is indicated by the steadiness of the expiratory position of thorax and abdomen, i.e., the troughs of the curves form a straight line, or are only very slightly and slowly undulatory. However, even in Profound Sleep, alterations occur in the rate and depth of respiration. The modifications are for the most part slight; but isolated, deep inhalations, prolonged expirations, and temporary cessation of respiration are occasionally noted. In 15 of the 31 cases of Profound Sleep the respiration was very regular throughout the two-minute period. In 13 cases modifications in breathing of the types above mentioned rendered it slightly less steady. There were two instances of Cheyne-Stokes breathing of the moderate type and one instance in which expiratory position of the thorax sank and remained at a low level for several seconds. One girl, three weeks of age, exhibited the costal type of breathing. Of the three infants who stirred, two had fallen asleep sucking their thumbs; the other, immediately after feeding.

Costal movements are usually of the Skewed Hill and Dale type. Three types of abdominal movements were exhibited: Cusped, Cusped

with pause, and Skewed Hill and Dale. The Cusped type predominated.

Figure 6 is a record of Profound Sleep of a girl of five weeks.

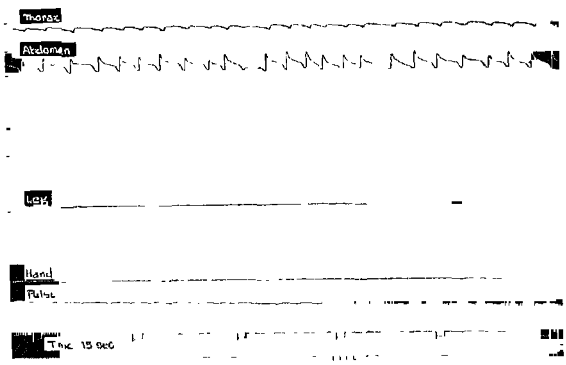

FIGURE 6

PROFOUND SLEEP

The subject is a girl, five weeks old. Breathing is unusually slow and slightly irregular. Note the lag of the costal movements, the sudden drop in the abdominal curve preceding each inspiration, and the absence of undulations in the breathing curves. The pulse curve shows Traube-Hering waves synchronous with the respiratory movements.

Breathing is very slow and quite regular. The amplitude of the abdominal movements far exceeds that of the costal movements. Note the lag of the costal movements and the sudden drop of the abdominal curve preceding inspiration. The Traube-Hering waves of blood pressure coincide with the breathing waves.

9. *Sleep Before Awakening*

Only six complete records were obtained of the type of sleep which precedes Quiet Awakening. This period is characterized by stirring, slight starts, and sudden alterations in breathing which at times appear likely to awaken the infant. Quiet intervals of slow, deep, and relatively regular respiration are interrupted by intervals of irregular respiration consisting of deep, sigh-like inflations of the lungs,

quick, deep inhalations followed by very slow expiration or temporary cessation of breathing, and quickened respiration or mixed deep and shallow breathing during which the curves usually become abruptly undulatory.

Breathing is markedly abdominal. The costal and abdominal movements are in general of the same type as those in Profound Sleep, but the curves are more undulant and the respiratory waves at times quite irregular.

10. *Restlessness*

Our study thus far indicates rather clearly that the more complete the state of rest of the organism, the more level the base line of the troughs and the more uniform the respiratory waves of the breathing curves. Restlessness is usually the first step in a perturbed state of the organism, the forerunner of fretting and crying. The relatively quiet and regular breathing typical of *Quiescence* becomes rapid and somewhat disorganized. Marked differences in the depth of successive inspirations and expirations transform the gentle undulations of the breathing curve into abrupt ascending and descending arches of varying heights and lengths. The troughs lose their orderly alignment. The curves become Notched and Dented (Figure 2, Type 3, *B, C,* and *E*) with Hill and Dale waves of unequal inspiratory and expiratory amplitudes. The costal and abdominal arches are usually concurrent and quite similar in character during moderate restlessness, but assume the appearance of *Fretting* curves as restlessness increases. The greater the restlessness, the higher and the more rugged the arches and the more irregular the respiratory waves.

The degree of restlessness is also indicated by the number and magnitude of the movements of head, hands, and legs. Small movements in scattered groups occur under conditions of slight irritability. When restlessness approaches the fretting stage, the movements are more rapid and abrupt and of constant occurrence. Figure 7 represents the behavior of a restless 22 weeks old girl. The breathing curves show considerable instability with respect to the total volume of air in the lungs on successive respirations and to the duration and amplitude of the respirations. For the most part, however, breathing is rapid and shallow. The almost constant changes in posture of the legs, indicative in the main of small, irregular altera-

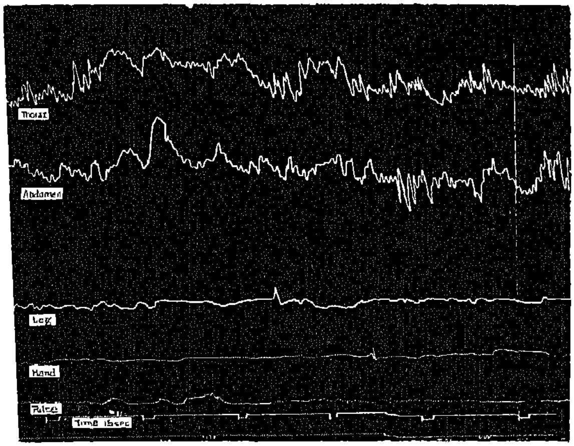

FIGURE 7
RESTLESSNESS
The subject is a girl, 22 weeks of age Breathing is generally rapid, shallow, and irregular in both rate and depth. The volume of air in the lungs on successive respirations is in constant flux. The small but continual alterations in the posture of the legs reflect the restless state of the infant. The movements of the head and hand are less conspicuous than those of the leg.

tions in degree of extension, reflect the restless state of the infant. The movements of the hands and head are less conspicuous.

11. *Fretting*

Fretting connotes a state of irritation just short of crying, involving wide-spread, generalized bodily activity. Emotional excitement, as indicated by the rate and amplitude of breathing and other bodily movements, waxes and wanes. Increase in excitement is denoted (*a*) by a sharp rise in the costal breathing curve (beginning of an arch), caused by a series of forceful, mixed deep and shallow respirations and catches in breath during which the volume of air inspired exceeds the amount expired until the lungs are well inflated; and (*b*) by marked flexion or extension of hands and legs (see Figure 8) or an increase in the number and violence of the movements of these parts and of the head. Diminution of excitement is indicated (*a*) by a drop in the costal curve, caused by the excess of expired air over inspired air in a subsequent series of

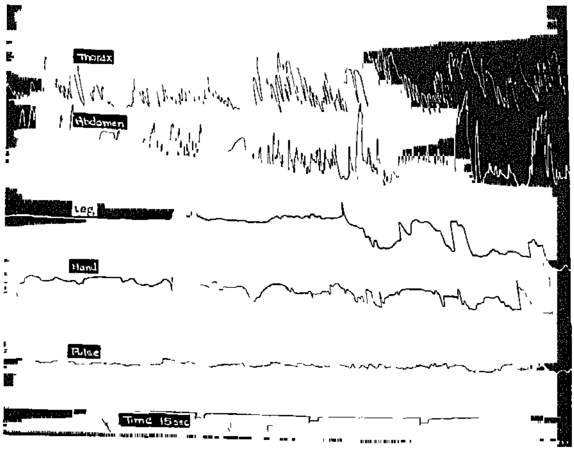

FIGURE 8

FRETTING

The subject is a boy, nine weeks old. Breathing is very rapid and irregular. Note that the respirations in general are much deeper than in *Restlessness* and that the costal movements are in the main somewhat larger than are the abdominal movements. The costal arches at the right signify that the infant is about to cry. The ascending portion of the curve is indicative of an increase in excitement; the descending portion, of a diminution in excitement. Note the tower-like forms in the abdominal curve, the sharp flexion of the legs followed by abrupt extensor thrusts, and the increase in scope of the hand and head movements as fretting continues.

respirations, and (*b*) by a reduction in muscular tension of hands and legs or a decrease in the number and violence of bodily movements. The abdominal curve also rises with increase in excitement; but, instead of paralleling the path of the costal curve, courses rapidly up and down in great sweeps. Its movements during this period are generally antagonistic to those of the costal curve. When fretting temporarily diminishes, breathing becomes unisonal, the rapid respiratory movements of the abdomen assume some semblance of regularity, and the curve remains at a lower level, or rises as the costal curve descends.

In short, breathing is more rapid, much deeper, noisier, and more disorganized, during periods of fretting than during restlessness. As the excitement increases, the thorax tends to inflate and stiffen, whereas the abdomen alternately contracts and expands. The un-

dulations of the breathing curves appear as spiked arches of the types shown in Figure 2, Type 3, *D* and *E*, and vary greatly in height and configuration. As a rule, the more marked the fretting, the higher and more rugged the arches and the greater the contractions and expansions of the abdomen. When fretting approaches the crying stage, catches in breath and rapid, shallow respirations occur with greater frequency among the deeper respirations, so that the arches are beset with numerous notches and small spikes.

Figure 8 presents the fretting behavior of a boy of nine weeks. Within 30 seconds of the time this record was taken, he was crying. Note the depth and rapidity of breathing. Costal respiratory movements are in general of somewhat greater magnitude than are the abdominal movements. Although both curves are very irregular, the abdominal curve is more erratic with its tower-like forms and its almost imperceptible notches.

12. *Crying*

Howell (35) classifies laughing, crying, yawning, sneezing, sobbing, and vomiting as modified respiratory movements. Crying takes several forms, among which are sobbing, sighing, the lusty cry of healthy infants, and the wail produced by pain. Breathing during crying is characterized by a deep, quick inspiration and a smooth or interrupted prolonged expiration (39). The movement of the air during the latter phase causes the vocal cords to vibrate and thus produces the sound. The venous congestion of the body and face is the result of the sustained expiratory phase. In contrast to quiet breathing, there is no pause between respirations; but there is a marked increase in the rate of respiration and in the volume of air respired. Temporary suspension of breathing, when it occurs, takes place between inspiration and expiration.

In the infant, crying represents the final step in violent emotional excitement. Overt manifestations of this fact are the excessive expansion of the chest, the extreme and rapid alterations in the volume of air in the lungs, the rapidity of breathing, the intensity of the vocalizations, and the number and violence of the movements of head, hands, and legs.

Crying sometimes occurs unexpectedly, even when the infants are apparently comfortably quiescent. On such occasions it is usually preceded by a series of rapid, deep breaths of about equal amounts

of inspired and expired air. In most instances, however, crying is anticipated by a period of restlessness or fretting. In the former case the transformation in the breathing pattern, as viewed from the record, is rapid and obvious. In the latter case, the transformation cannot always be detected, particularly when fretting precedes crying.

Sustained crying may consist of (*a*) a series of short, sharp, staccato-like screams or yells emitted in rapid order on successive, deep expirations; (*b*) prolonged cries, each lasting several seconds; or (*c*) a combination of short and prolonged cries. In any case crying usually begins while the lungs are well inflated, or in terms of the costal curve, at the top of an arch. When inflation during crying, and fretting as well, is not completed on a single inspiration, the lungs are filled as a result of the domination of the inspiratory phases in a complicated series of catches of breath and deep and shallow respirations.

Our records show that crying begins on a high costal curve at the completion of a sudden, deep intake of air. The abdominal curve also rises and then, except in the instance of staccato-like cries in which abdomen and chest inflate and deflate in unison with each scream, follows a course quite dissimilar to that of the costal curve. On short, explosive cries both curves consist of a series of sharp, lofty peaks, inspiration and expiration are usually of almost equal amplitude, and the expiratory position of chest and abdomen are fairly constant.

In prolonged cries of fairly uniform intensity the air is forced from the inflated lungs in a series of explosive, expiratory movements interrupted by minor inspiratory movements and catches of breath. Although the deflating phase of the costal curve varies in pitch and is never smooth, it is devoid of marked breaks. A prolonged cry which waxes and wanes in intensity produces a very rugged curve. The costal curve frequently remains at a high elevation at varying levels for long periods of time. This is due to the fact that the thorax after expanding stiffens its musculature against collapse. Hence costal respiratory movements at this time are necessarily small. The movements of the abdomen are larger and more violent. Marked expansion, sharp contraction, and stiffening, occurring with great suddenness and in irregular order, cause the breathing curve to sweep abruptly up and down and thus describe a series of high, tower-like arches. The abdomen and thorax may expand and

contract in unison so that the arches of the two waves are coincidental. The abdomen may contract or stiffen as the thorax expands, or the abdomen may expand and contract several times during a single thoracic expansion. Each cry usually starts on a major downstroke of the abdominal curve. However, during a single prolonged cry the expiratory movement may shift several times from abdomen to thorax.

There is a striking similarity between the breathing curves of severe *Fretting* and *Crying*. However, with the exception of staccato-like crying, the excursive movements of thorax and abdomen are of greater scope, and respiration as a whole is faster and shallower in crying. As in the instance of *Pleasurable Activity,* the height and irregularity of the costal curve serve to indicate the extent of the excitement. In this connection even fleeting emotional experiences, pleasant or unpleasant, leave their traces on the breathing curves. Repeated small elevations in the costal curve, anticipatory of later great excitement, attest to the sensitiveness of the breathing mechanism.

The breathing curves during crying abound with spikes, dents, and notches (Figure 2, Type 3, *D* and *E*). A dent is indicative of a momentary check of respiration, produced by closure of the glottis. A notch, however, signifies that the inspiratory or expiratory movement, as the case may be, has been interrupted by an abbreviated, opposed respiratory movement. Hence the arc of the breathing curve lying between two notches, or between a notch and a dale, represents a respiratory movement and is herein so regarded. The frequency of these small secondary respirations has the effect of greatly increasing the respiratory rate. In this connection Deming and Washburn (12) found breathing rates as high as 114 respirations per minute during crying. Canestrini (7) places the rate between 50 and 70. The relatively low rate reported by Canestrini may be due to the fact that he counted only the greater breathing movements—major and minor arches.

The movements of the legs correspond closely with the abdominal movements in loud, prolonged crying. As the abdomen expands, the legs are raised quickly with the knees sharply flexed or stiffly extended. At the climax of each cry the legs are thrust sharply downward several times in succession or stiffly extended. At other times the feet are braced against the bed pad to arch the trunk. With steady crying but less violent display of excitement, the action of

the legs, despite a certain rigidity, resembles well executed stepping movements. As crying temporarily subsides, the movements diminish in number, vigor, and scope as the legs gradually go to extension. In general, marked abdominal expansion is accompanied by elevation of the legs, contraction of the abdomen by extension of the legs.

The hands, usually erected at the sides of the chest or head, shakily paw the air or move in jerkily over the chest and clutch at the clothing as they open and close. The movements become more pronounced during the more violent stages of crying.

Agitated, aimless movements of the head are accompanied by irregular increases and decreases in brain volume. The fontanel curve rises and falls with each cry, the extent of the rise usually corresponding with the intensity of the sound. Thus the duration and intensity of each cry can be determined by the length and height

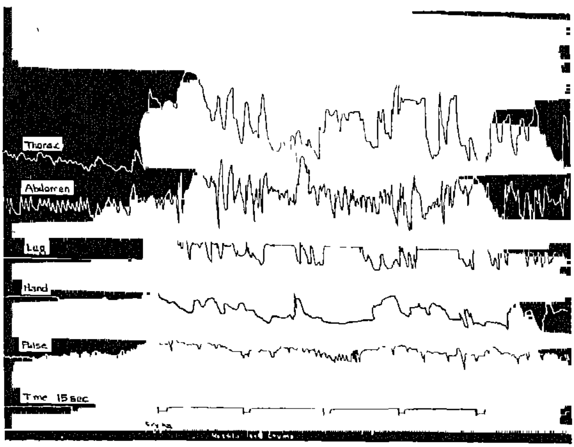

FIGURE 9

CRYING

The subject is a girl, 17 weeks of age. Both short and prolonged cries are shown in this record. The duration of each scream can be determined from the pulse curve, inasmuch as the curve ascends and descends with each vocalization. The chest is well inflated. Note that the general level of both breathing curves rises as crying starts. The abdominal movements are in general more abrupt and more irregular than are the costal movements. Note the sharp flexion of the leg and the quick strong extensor thrusts which accompany violent outbursts of crying. The scope and force of the movements of the hand are maximum in this situation and the tendency is toward extension.

of the individual swells on the fontanel curve. Figure 9 is a record of mixed short and prolonged cries, as indicated by the pulse curve. The record shows that in this instance thoracic inflation exceeds abdominal inflation. Note the sharp flexion of the legs and the quick, strong extensor thrusts.

The costal type of breathing predominates during crying. When emotional excitement runs high, antagonistic breathing movements occur and abdominal contraction subserves thoracic expansion. When the excitement subsides the movements tend to be unisonal. In this connection it will be noted that the breathing curves of *Fretting* and *Crying* are consistently more abrupt and angular than those of the pleasurable situations.

13. *Quieting After Crying*

Respiration after crying is rapid, generally shallow, and marked by occasional deep respirations, sighs, periods of quickened respiration suggestive of a new outburst of crying, and small abrupt alterations in elevation of either or both thorax and abdomen. Breathing is of the unisonal type during the early stages of quieting, and the amplitude of the costal movements equals that of the abdominal movements. As composure is gradually restored, breathing becomes abdominal in type. The rate diminishes, costal movements become smaller, and the abdominal movements become larger.

The rapidity with which composure is restored after crying is indicated by the speed of deceleration in the breathing rate, by the grade of the descent of the breathing curves, and by the frequency and height of their undulations. As a rule the quieting-down process usually lasts several minutes. The respiratory rate decreases very slowly, the breathing curves fall rapidly at the start and then sink very gradually, and the short, abrupt undulations which occur in rapid succession immediately after the cessation of crying give way by scarcely perceptible changes to the slow, gentle undulations of quiescence.

It is interesting that the after-effects of crying are reflected more strongly by the activities of the thorax and abdomen than by movements of other parts of the body. The head, hands, and legs become strangely quiet and, except for a few minor movements at widely separated intervals, are quite relaxed. Movements of these parts usually occur concurrently. The legs, however, are somewhat more active than the hands or head.

14. *Cog Wheel Waves*

Respiratory waves of the cog wheel type were exhibited on the costal curve by about two-thirds of the infants during sleep. The cogs in all cases synchronized with the pulse beats and were undoubtedly produced by cardiopneumatic movements (30, 31). On some occasions these movements were strong enough to be registered on the abdominal curve. This type of respiratory wave is not included among the types illustrated in this paper. Due to the speed of inspiration, the cogs usually occurred on the expiratory aspect of the wave. In some cases, however, when the breathing was especially slow, and inspiration was more prolonged than usual, the ascending portion of the wave was frequently marked by a cog.

H. Pulse Rate

1. *Fetal and Infant Heart Rate*

The fetal heart beat can usually be heard in the eighteenth week (15, 47). The beats show pronounced variations in rate which apparently carry no serious significance (47). Pflüger (46) observed the heart beat in a 3 weeks' human embryo which had been removed from the uterus. Sontag and Richards (53) made careful stethoscopic observations of the fetal heart rate *in utero* from the fifth month to birth. The observations extended over a five-minute period in each case. They found a gradual drop in heart rate during pregnancy from about 156 to 140 beats per minute. The mean rate for the last two months was 142.1 for 34 cases; whereas the mean rate for the newborn was 133.7 for 21 cases. Heart rates of 108 to 160 beats per minute have been reported elsewhere (1, 15, 39, 48) for the full term fetus, although the normal rate is believed to be between 120 and 150. Records of the neonate indicate heart rates varying from 95 to 156, with the normal range approximately the same as that of the fetus (1, 15, 37, 39, 43, 48). The rate during the first year is generally placed at about 120 (15, 27, 35, 37, 57).

2. *Variability of Heart Rate*

The heart rate, according to Boas and Goldschmidt (3, p. 20) "fluctuates from moment to moment to manifold intrinsic and extrinsic stimuli." The "frequency may be considered a most sensitive gauge of the physiologic processes of the body." They argue

that in view of these fluctuations there is no normal heart rate and therefore they establish what is known as a basal rate which is obtained during the "post-absorptive resting period" following the early morning awakening before rising. Sutliff and Holt (57) likewise recognize the advantage of a basal rate. Sontag and Richards (53, p. 23) state that even in fetal life "the heart rhythm is an extremely variable phenomenon." Single observations rendered rates ranging from 115 to 185 beats per minute. Pronounced variations in heart rate during pregnancy have also been reported elsewhere (47). The rate in infancy also varies over a wide range and the rhythm is more irregular than in later life (48). Under normal conditions it is believed that the infant rate may vary as much as 30-50 beats (43, 48, 55). Sutherland (55) says there are regular diurnal variations.

Guy (27) cites observations by Billard which indicate that the difference between minimum and maximum pulse rates of neonates may be as great as 100 beats (80-180). However, rates as low as 80 are questionable. Guy himself estimates that the minimum rate at one year is about 108 and the maximum rate, 158. Excitement may send the rate above 200 (48). Holt and McIntosh (34) state that heart rates of 200 to 250 which begin and end very abruptly have been reported for children. A type of irregularity frequently observed in childhood consists in an increase in the pulse rate on respiration, followed by a decrease during expiration (3, 35). Sutliff and Holt (57) found that variability of heart action was greater in children than in adults and greater in females than in males. Fluctuations in rate may occur slowly or rapidly, depending on the subject's disposition and the nature of the stimulation (10, 26, 35, 57, 60).

3. *Conditions Affecting Heart Rate*

Heart activity increases with feeding, muscular exercise, crying, excitement, rise in bodily temperature, and fall in blood pressure (26, 27, 35, 43). Acceleration in rate has also been reported in instances of mental work, infection without fever, and sensual and intellectual unpleasant experiences (13, 26, 58). Diminution of heart rate occurs with rest, sleep, lowering of bodily temperature, rise of blood pressure, cessation of excitement, and recovery from acute infections (26, 27, 35, 43). It is stated that pleasant sen-

sual and intellectual experiences, and attention to visual and auditory stimuli may cause a deceleration in the rate (13, 35).

Heart action accelerates rapidly with muscular activity (2, 3, 35) and diminishes rapidly at cessation of light exercise and slowly after exhausting work (35). The range in heart rate in just ordinary activities is considerable (3). It has been noted that with the fetus and also the neonate fluctuations in the rate are greater during activity than during quiescence (26, 53). During exhausting work the acceleration in rate is extraordinary. Increases of 50 to 100 beats per minute have been reported for adults (2, 35) and a mean increase of 114.9 for boys of 9 to 15 years of age (3). Maximum heart rates at this time are usually between 160 and 175 beats per minute for adults although higher rates, in one instance 246, have been reported (32). The mean maximum rate for boys is stated to be 182.6 (3), but individual rates higher than 200 are also evidenced. The maximum rate is said (3) to be determined by the speed and amount of work rather than by the initial pulse rate or duration of the work.

Even alterations in posture can effect a marked change in heart frequency. As a rule the heart rate decreases as the body passes from the erect to the horizontal position and increases when the change in position is reversed (3, 27).

There is general agreement that the heart rate accelerates with feeding (2, 3, 27, 35). The rise in rate is probably greater in infancy than in adulthood (27). There is also an increase in the force of the beat (35). Evidence gathered from observations on three fetuses (53) indicates a higher fetal heart rate one hour after the maternal breakfast than just before this meal. On the other hand, the rate immediately after breakfast was lower than that before breakfast. It is suggested that the heat of the food or the bodily activity involved in feeding may account for the higher heart rates recorded during meals by other investigators.

The heart rate is lower during sleep than during waking for both infants and adults. Although observations in fetal life are as yet meager, the evidence on hand indicates a "slight tendency" for the fetal heart rate to be lower during maternal sleep than before or after such sleep (53). The difference between heart rates of young infants during active periods and during sleep is given as 40 to 50 beats per minute by Benedict and Talbot (2). The rate during sleep at this period of life is about 120 (48). Guy (27) states the drop

in pulse rate is greater for children than for adults. Parsons and Barling (43) state that the beats are more irregular during sleep and that they normally lengthen during expiration and shorten during inspiration. The reduction in rate is in part a function of the duration of sleep (3). According to Boas and Goldschmidt (3) certain changes in physiological functions occur during sleep which may account for the lowered heart rate.

Emotional excitement has about the same effect on the action of the heart as does physical exertion. There is an increase in the speed and strength of action of the heart and the impulses become diffuse and disorderly (3, 21, 35, 43, 58, 60). Even fleeting emotions may cause fluctuations in the rate (35, 48). Day, Smith and Klingman (10) report a pulse rate of 185 beats per minute during crying in an infant of one month and a rate of 165 in a child of 19 months. With abatement of excitement the rate may fall slowly or rapidly in accordance with the subject's disposition (60). The pulse is often very irregular in the slow phases following excitement when the rate is lower and the beats stronger (43).

Experiments by Canestrini (7) on young infants indicate an increase in pulse rate with auditory and olfactory stimulation. Tactile stimulation with cold resulted in irregularity of pulse rate and in many cases an increase in rate. Sweet tastes had a quieting effect on the pulse, whereas salt and bitter tastes produced irregularities in the fontanel curve.

4. *Pulse Rates in the Different Situations*

Pulse rates for the different situations are presented in Table 1 and Figure 10. The most rapid pulse rates were observed during crying. This was probably due to the fact that both bodily activity and emotional excitement were greatest at this time. The pulse quickened sharply with the first deep inspiratory movement and appeared to vary in rate with the amount of energy expended. Fluctuations in pulse rate were very rapid and the differences between the maximum and minimum crying rates for individual infants frequently exceeded 100 beats per minute. The total mean maximum pulse rate per minute for the 35 infants over very short intervals was 218.2. The median was 220 and the range, 168-276. In seven instances the rates exceeded or equalled 250. The three highest rates were 258, 268, and 276. The total mean minimum pulse rate was 170. The median was 168 and the range 131-208. The three low-

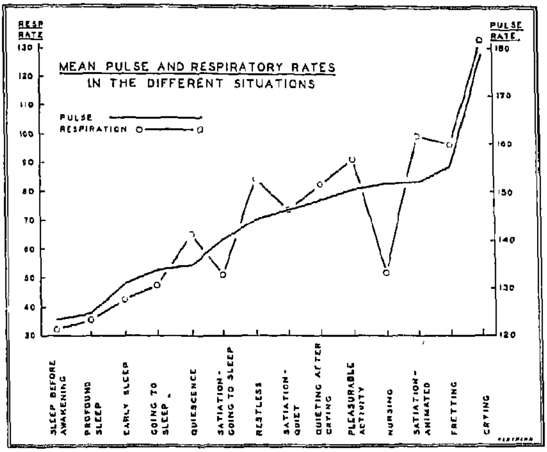

FIGURE 10

MEAN PULSE AND RESPIRATORY RATES IN THE DIFFERENT SITUATIONS

est rates were 131, 142, 148. The mean rate for all infants was 179.3 and the range 136-220.

The next highest pulse rates occurred in situations wherein there was also a high degree of bodily activity or emotional excitement, viz., *Fretting, Satiation-Animated, Nursing,* and *Pleasurable Activity.* The mean pulse rate in these situations was between 150 and 155. The range and individual differences between maximum and minimum rates were considerably less than for *Crying.* Mean pulse rates between 140 and 149 were found for situations in which infants were either restless or resting after a period of excitement or vigorous activity. These situations were: *Quieting after Crying, Satiation-Quiet, Restlessness, and Satiation-Going to Sleep.* The mean pulse rate was between 129 and 135 for the very quiet infants in situations such as *Quiet Awakening, Quiescence, Going to Sleep,* and *Early Sleep.* The lowest rates were recorded during *Profound Sleep* and *Sleep before Awakening.* The mean pulse rates in these situations were 123.5 and 123.2. In summary, it may be stated that the more quiescent the infant, the lower the pulse rate; and the lower the pulse rate, the smaller the fluctuations in rate and the smaller the range of the measures for the group.

Maximum pulse rates, registered during *Crying,* apparently have

no connection with the rates during *Profound Sleep.* The lowest pulse rate, 106, was registered by a boy of 16 weeks who for a short period of crying had a high pulse rate of 256, an increase of 147 beats per minute. The highest pulse rate during *Crying,* 276, was registered by a girl of 22 weeks whose mean rate during *Sleep* was 119, the seventh lowest rate. The difference between the two rates in this case was 157. The increase in pulse rate from the total mean rate in *Profound Sleep* to the total mean maxmium rate in *Crying* was 94.7 beats. In this connection it is recalled that Boas and Goldschmidt (3) report an average difference of 114.9 beats per minute between the maximum heart rate during exhausting exercise and the rate in recumbent resting before exercise for 27 boys of 9 to 15 years of age. In passing it was noted that abatement of excitement, pleasant or unpleasant, was in all cases accompanied by a decline in the pulse rate, an increase in the amplitude of the beat, and a very irregular pulse wave.

I. Breathing Rate

Respiratory rate, rhythm and amplitude, and the conditions which affect them have been subjected to much study. Excellent reviews of the literature may be found in the investigations conducted by Gesell (18), Greene and Coggeshall (22), Haldane (29), and Means (41). For an admirable treatment of the evolution of respiration, its purposes, and the control of ventilation, circulation, and energy supply, the reader is referred to two articles by Gesell (19, 20).

1. *Normal Breathing Rate during Infancy*

The breathing rate at birth has been variously reported (6, 7, 15, 39, 48, 54) to be between 30 and 62 respirations per minute. The rate at one year is somewhat lower, ranging from 25 to 44 respirations per minute (6, 15, 39, 48).

2. *Relationship of Breathing Rate to Certain Physiological Functions*

That the breathing rate increases with muscular exercise is well known (35, 54). Acceleration in rate also occurs with crying (7, 12), sensory stimulation (7, 13), excitement (13), and change of posture from lying to sitting to standing (6). The rate diminishes

when the conditions which effect acceleration cease or are reversed. It also diminishes with certain other forms of stimulation and excitement. Bohr and Rubow, cited by Greene and Coggeshall (22), found that the volume of the chest increased during work and decreased after work. However, slight muscular exercise may not effect any change in thoracic volume (22). Eng (13) says that pain and pleasant emotions cause an acceleration in the breathing rate, whereas depression and unpleasant tastes result in retardation of the rate. When excitement occurs under conditions of displeasure, respiration accelerates, becomes irregular, or remains unchanged. Pleasant tastes may quicken or retard the breathing rate. Fright at first results in momentary inhibition of respiration, after which it accelerates and finally slows. Peretti (45) reports that sudden strong excitations of certain sense organs effect immediate modifications in breathing which in some instances are very marked. The character and duration of the breathing vary with the nature of the stimulus. Canestrini (7) found an acceleration in respiratory rate in response to olfactory and cold tactile stimulation. In the instance of olfaction the breathing also became deeper and irregular. Sweet gustatory stimuli produced regular breathing; whereas salty and bitter tastes caused it to be irregular. Visual stimulation produced varying respiratory responses depending on the physiological state of the infant. Responses to sound stimuli varied. When infants were asleep respiration became irregular in depth and its rate temporarily dropped. When they were awake responses to strong but not startling stimuli consisted of irregular breathing of diminished depth. Responses to weak auditory stimuli were negative.

3. *Breathing during Sleep*

The respiratory rate of both infants and adults is lower during sleep than in waking (12, 15, 22, 29). Deming and Washburn (12) for example, report that the mean breathing rate for young infants is 59 respirations per minute during waking and 41 during sleep. The rate is also lower in profound sleep than in light sleep in the case of infants (12). Haldane (29) found that for the adult the rate dropped from 15 respirations per minute in the erect or sitting position to 7 or 8 in the recumbent position. Although inspiration is faster than expiration, there is a retardation in speed of both phases of the breathing cycle during sleep (7). The mean respiratory

rate for infants is reported to be between 40 and 50 breaths per minute (7, 12, 15, 48), but rates ranging from 25 to 76 have been observed (12). Alterations in the depth of breathing occur but they are not as great as those in waking (12, 22). Respiration is said to be shallow and somewhat irregular (12, 15, 22, 48). This is thought to be "due to the horizontal position of the ribs and the weakness of the accessory muscles of respiration" (48). On the other hand Feldman (15) states that breathing is deeper and more costal in sleep. Reed and Kleitman (49), however, failed to find any pronounced difference between waking and sleeping types of breathing. Undulations in the breathing curves of adults, according to Greene and Coggeshall (22), are affected more by inspiratory movements than by expiratory movements. Deming and Washburn (12) found that both regular and periodic types of breathing were common during the sleep of young infants. The slow type—quick inspiration followed by very prolonged expiration—occurred less frequently and then only in infants not older than six weeks. The mean breathing rate of 41 respirations per minute was lower than the waking rate, 51, and the respirations were more uniform. No correlation was found between respiratory rate and age or bodily weight.

4. *Respiratory Rates in the Different Situations*

Inasmuch as the respiratory rate generally increases with physical activity and excitement and decreases with quiescence, it is essential to state the conditions under which the rates are obtained. The conditions for which respiratory rates were obtained in the present study are presented in Table 1.

The order of the respiratory rates, with three exceptions, corresponded closely with that of the pulse rates for the fourteen situations (Figure 10). The highest mean breathing rate, 133.3 respirations per minute, was established during *Crying;* the lowest rate, 32.3 during *Sleep before Awakening*. The mean breathing rate for crying, exclusive of the secondary breathing movements, was 73.8, the median 72, and the range 38-112. In general, as in the case of pulse rates, respiratory rates were high in situations in which bodily activity or emotional excitement was marked, and low in situations wherein infants were asleep. Breathing was particularly rapid (90-100) during *Satiation-Animated, Fretting,* and *Pleasurable Activity,* but

slowed down rapidly during *Sleep* from about 50 to 33.9 in *Profound Sleep*. In *Restlessness* and in *Quiescence*, the respiratory rates were relatively higher than the corresponding pulse rates, but not to a great extent. In *Nursing*, the conditions were significantly reversed. Breathing was relatively slow with a rank of 10 among the rates; whereas the pulse rate was rather high. Normally, breathing and pulse rates accelerate with increase in bodily activity. However, inasmuch as a low respiratory rate is best suited to sucking, the infant compensates for the slower breathing by an increase in its depth (Table 1).

J. Relation Between Pulse Rate and Breathing Rate

Breathing rate and heart rate both diminish with age. Estimations of the rate of breathing of quiet infants at birth vary from 30 to 62 respirations per minute. Records at one year show rates varying from 25 to 44. The adult rate is generally placed at 16-18 respirations per minute (6, 15, 39, 48). The normal heart rate is 120-150 beats per minute for the neonate and about 120 beats per minute during the first year. The heart rate for adults is 70-75 (1, 3, 27, 35, 57). Inasmuch as both respiratory and pulse rates of infants fluctuate rapidly during the waking hours, the widely varying rates reported in early life are not surprising. In the present study the breathing rate for quiet infants ranged from 47 to 76 respirations per minute and the pulse rate from 119 to 144 beats per minute. The breathing rate during sleep was 19-66 respirations per minute and the pulse rate, 106-154 beats per minute.

1. *The Pulse-Respiration Ratio*

The ratio of pulse rate to respiratory rate is said to be about 3 or 4 to 1 for both infants and adults (15). The ratio at birth is about 3 to 1 and slightly higher during sleep than in waking. Canestrini (7) reports 120 to 140 pulse beats for breathing rates of 40 to 50 respirations per minute. Guy (27) found that for adults the pulse-respiration ratio was about 3 to 1 in the standing position; 3.35 to 1 in sitting; and almost 5 to 1 in lying. The increase in the number of pulse beats per respiration from standing to lying is accounted for by the slower breathing in the latter position.

The present study shows that the pulse-respiration ratio varies with the physiological state of the organism. In general, the num-

ber of pulse beats per respiration is low in situations associated with excitement or marked physical activity, and high in situations in which bodily activity is at a minimum. This is due to the relatively greater acceleration in the respiratory rate than in the pulse rate with increase in physical activity and excitement. The ratios for the different situations, based on the mean measures of Table 1 are listed in order below.

Sleep preceding awakening	3.81
Profound sleep	3.64
Early sleep	3.04
Nursing	2.94
Sleep between feedings	2.79
Satiation—sleep	2.75
Quiet awakening	2.14
Sucking thumb	2.07
Satiation—quiet	1.98
Restless	1.71
Pleasurable activity	1.64
Fretting	1.58
Satiation—animated	1.53
Crying	1.35

K. Costal and Abdominal Respiratory Movements

1. *Amplitude of the Respiratory Movements*

Table 1 shows that the mean amplitude of the costal respiratory movements was generally greater in the *Nursing* and *Pleasurable Activity* situations, and somewhat smaller during *Restlessness* and in the period following *Nursing*, than in the remaining situations. The amplitude of the abdominal movements was greatest during *Profound Sleep* and *Sleep before Awakening* and least during *Satiation-Animated* and *Quieting after Crying*. The abdominal movements were also somewhat undersized in *Restlessness, Pleasurable Activity,* and *Quiescence.*

The situations in which the mean amplitude of the movements of both abdomen and thorax in each case exceeded the general mean amplitude were *Sleep before Awakening, Profound Sleep, Early Sleep,* and *Awakening.* In *Satiation-Animated Restlessness,* and *Quiescence* the conditions were reversed. The abdominal movements were relatively large and the costal movements relatively small in *Satiation-Quiet* and *Satiation-Going to Sleep;* whereas in

Nursing and *Pleasurable Activity* the costal movements were relatively much greater than were the abdominal movements.

In the majority of the situations the mean amplitude of the abdominal movements far exceeded that of the costal movements. In fact, during *Sleep before Awakening, Profound Sleep* and *Satiation-Quiet,* the ratio of the amplitudes was greater than 2:1. Costal and abdominal movements were equal in magnitude (mean and median) in *Pleasurable Activity* and almost of equal size in *Quieting after Crying.* Differences in amplitude were also small in *Nursing* and *Satiation-Animated.* Finally, of the 12 situations represented, differences in amplitude between abdominal and costal movements were greater during repose than during periods of activity.

Respiratory movements during *Fretting* and *Crying* showed rapid and extreme variations in amplitude. The movements at times were very large and at other times very small, so that in many instances the distribution of their measures was bi-modal. For this reason measures of central tendencies of the amplitudes of costal and abdominal movements were omitted. However, the character of the breathing in these two situations is well revealed by other measures which do appear in the table. In passing it should be mentioned that in *Fretting* and *Crying* the marked difference in magnitude of successive inspiratory and expiratory movements makes measurement of amplitude of the breathing movements an exceedingly complicated process.

2. *Relative Magnitude of Costal and Abdominal Respiratory Movements*

The ratio of costal amplitude to abdominal amplitude in the different situations, as shown in Table 2, was determined in terms of their mean measures. In general the ratio is lower for those situations in which excitement is absent. The ratio is highest for *Pleasurable Activity* and lowest for *Sleep before Awakening.* In the former case the respiratory rate is rapid and the breathing very variable in depth. The high ratio in the feeding situation is principally due to the general increase in the amplitude of the costal movements without any appreciable change in the amplitude of the abdominal movements.

Ratios for *Crying* and *Fretting* could not be determined by this method. However, some indication of the relative magnitude of

TABLE 2

RELATIVE AMPLITUDE OF COSTAL AND ABDOMINAL RESPIRATORY MOVEMENTS IN DIFFERENT SITUATIONS

Situation	Costal abdominal-ratio
Pleasurable activity	1.00
Quieting after crying	.94
Feeding	89
Satiation-animated	.83
Restlessness	.74
Sucking thumb	.70
Quiet awakening	.57
Going to sleep between meals	53
Early sleep	.48
Profound sleep	.48
Satiation—quiet	.46
Satiation—going to sleep	.46
Sleep before awakening	.43

costal and abdominal movements in these situations may be obtained from the measures of their maximum amplitudes and the extreme heights of the two breathing curves. The evidence from these sources points to relatively high ratios in both instances (Table *A*).

TABLE A

COSTAL-ABDOMINAL RATIO

	In terms of maximum amplitudes	In terms of the height of the breathing curves
Crying	.81	.80
Fretting	.76	.77

It will be noted that there is close agreement between the ratios for each situation.

The increase in magnitude of the respiratory movements from quiescence to excitement is relatively greater for the costal movements than for the abdominal movements. In fact, the costal movements on numerous occasions are larger than the abdominal movements. For example, in each of the following situations: *Pleasurable Activity, Quieting after Crying, Nursing, Satiation-Animated, Fretting,* and *Crying,* at least 40 per cent of the infants exhibited costal movements which equalled or exceeded abdominal movements in magnitude. Costal movements were at least as large as abdominal movements in 10 per cent of the cases of *Going to Sleep* after crying, and in 5 per cent of the cases of *Satiation-Quiet.*

3. *Minimum and Maximum Respiratory Movements*

Excitement characteristically disorganizes the breathing process. As in the case of other bodily movements, respiratory movements varying in amplitude from one extreme to the other follow one another rapidly in great disorder. The thorax and abdomen surge violently up and down and then suddenly stiffen for short or protracted periods during which the magnitude of the respiratory movements is very much reduced.

The minimum and maximum measures of respiratory movements reveal that the shallowest and also the deepest costal movements occur more consistently in situations in which excitement is a strong factor. As a result one should expect the range in amplitude of the movements to be greater for these situations than for the others. Table 1 shows that minimum costal and abdominal movements are smallest during *Crying, Fretting, Pleasurable Activity,* and *Satiation-Animated,* and relatively large during *Sleep;* and that whereas maximum costal movements during these exciting situations are larger than those in repose, maximum abdominal movements are in some cases larger and in other cases equal or smaller. However, differences in amplitude between maximum and minimum movements are in all cases greater in the four exciting situations.

Costal and abdominal maximum amplitudes and alterations in amplitude are also large in *Nursing* but relatively much greater for the costal movements than for the abdominal movements. It has been suggested that the increase in the amplitude of the costal movements and the decrease in the breathing rate in this situation are due in large measure to the important rôle of the thorax in producing the negative pressure essential for sucking.

Differences in amplitude between costal movements and between abdominal movements were relatively small in *resting* and *sleeping* situations. In general the more quiescent the infant, the more uniform in amplitude the respiratory movements.

4. *Extreme Height of the Breathing Curves*

The breathing curves attain their greatest heights in the exciting situations, particularly during *Crying* and *Awakening.* (The latter situation is discussed at greater length in a later section of this paper.) In contrast to their magnitudes in the quiet situations, costal movements are always relatively larger than abdominal movements in

these situations. This increase in costal amplitude is particularly marked in *Satiation-Animated* and *Awakening,* wherein the two breathing curves are about equal in height. According to Table 6 the costal curve attains its greatest height in *Awakening,* and the abdominal curve is correspondingly high. Note in *Nursing* and in *Quieting after Crying* that, whereas both measures are relatively low, the mean altitude of the costal curve is greater than that of the abdominal curve. Breathing curves are generally lowest during *Sleep* and *Quiescence.* The mean height of the costal curve (4.8 mm.) is minimum in *Profound Sleep.* The fact that the mean amplitude of the individual respiratory movements in this situation is 3.3 mm, is an indication of the great uniformity of the breathing. The mean height of the abdominal curve is minimum during *Quiescence.*

5. *Number of Undulations*

The number of undulations per minute is large in the exciting situations and small in the quiet situations. According to the median measures, the greatest number of undulations (25 costal and 20 abdominal) occurred in *Crying;* the smallest number (one costal and one abdominal), in *Profound Sleep.* Undulations were also very numerous during *Pleasurable Activity* and *Satiation-Animated,* and scarce during *Late Sleep* and *Early Sleep.* As a rule the costal undulations outnumbered the abdominal. During *Sleep,* however, the number in each case was about the same. These major swells in the respiratory curves varied greatly in height and length. The kinds of undulations which prevailed in *Crying, Fretting, Restlessness,* and *Awakening* have already been illustrated. But it should be noted that extreme modifications in the configuration of these types were manifold. The truly undulatory curves were evidenced in the quiet situations. The slowest and most gradual alterations in the expiratory position of the chest and abdomen occurred during *Profound Sleep.* In *Nursing,* alterations in the position of the chest were more pronounced than those of the abdomen. Occasionally, however, there was complete absence of undulations during the sucking activity.

Summarizing: the higher and more rugged the undulations in the breathing curves, the more disorganized the breathing; and the fewer and gentler the undulations, the more uniform in time and depth the respiration.

6. *Number of Troughs Out of Alignment*

Sudden changes in the expiratory position of the chest or abdomen throw the troughs of the breathing curves temporarily out of alignment. The ruggedness of the curves is due as much to these changes as to alterations in the amplitude of inspiration and in the duration of the respiratory movements. In quiet respiration the expiratory position shifts slowly up and down, imparting a gentle undulatory movement to the breathing curves. During excitement the changes in the expiratory position are large and abrupt. Major shifts involving several respirations result in high, irregular arches. Minor shifts which affect only from one to three respirations produce small arches. When excitement runs high, minor changes occur within the major changes, with the result that the breathing curve consists of one or more small arches within a greater arch, as in Figure 9. Minor arches, caused by yawning, abrupt changes in amplitude or one or more expiratory movements, and interruptions of the breathing process due to changes in bodily posture, also occur in quiet respiration.

In general, the number of minor arches (troughs out of alignment) increased with the breathing rate. They occurred with great frequency in exciting situations and with much less frequency in sleep. The frequency was highest during *Crying* with a median number of 38 costal and 34 abdominal arches per minute. The smallest number occurred during *Profound Sleep*, viz., two costal and two abdominal arches per minute. In most of the situations there was a slightly greater number of these irregularities in the costal curve than in the abdominal curve.

7. *Height of the Highest Trough*

Just as the maximum altitudes of the breathing curves indicate the degree of expansion of chest and abdomen at the completion of the deepest inspiration, the altitudes of the highest troughs indicate to what extent expansion is maintained after expiration has occurred. Measures of the maximum heights of the troughs indicate that the expiratory positions of chest and abdomen are at great heights in the exciting situations and remain relatively low during *Quiescence* and *Sleep*. Thus it appears that the height of the troughs in the different situations corresponds closely with the height of the curves. The highest troughs occurred during *Crying;*

the lowest, during *Profound Sleep*. According to the mean and median measures, costal troughs were higher than abdominal troughs in two situations, viz., *Nursing* and *Satiation-Going to Sleep;* and of about the same height as the abdominal troughs in three other situations, viz., *Satiation-Animated, Going to Sleep*, and *Sleep Before Awakening*.

L. Head, Hand, and Leg Movements

The number of movements per minute of head, hand, and leg is a good indication of the physiological state of the infant in the different situations. Table 1 shows that the number of movements is greatest for the exciting situations of which *Crying* leads the list with an average of 78.8 head movements, 75.7 hand movements, and 70.7 leg movements per minute. *Profound Sleep* foots the list with an average of a mere fraction of a movement in each case. All movements, large and small, are included in these figures. The situations and their rank order with respect to the number of movements of the head, hand, and leg are presented in Table 3. It will

TABLE 3

Rank Order of the Situations with Respect to the Number of Head, Hand, and Leg Movements Occurring per Minute

	Movements of			
Situation	Head	Hand	Leg	Head, hand, and leg combined
Crying	1	1	1	1
Satiation—animated	2	3	2	2
Fretting	3	2	4	3
Pleasurable activity	4	4	3	4
Restlessness	5	5	5	5
Quieting	7	6	6	6
Satiation—quiet	6	7	7	7
Satiation—going to sleep	8	11	8	8
Nursing	10	8	9	8
Sleep before awakening	9	9	11	10
Quiescence	12	10	10	11
Going to sleep	11	12	12	12
Early sleep	13	13	13	13
Profound sleep	14	14	14	14

be noted that the order of the situations is in fairly close agreement with that of Figure 11.

M. Relative Irregularity of the Breathing in the Different Situations

From the description of the breathing in the different situations and the foregoing measures of the respiratory curves it is apparent that breathing is most uniform in rate and depth during *Profound Sleep* and increases in irregularity with excitement and muscular activity.

The relative amount of disorder in breathing in the different situations is shown in Figure 11. The curves indicate the rank order

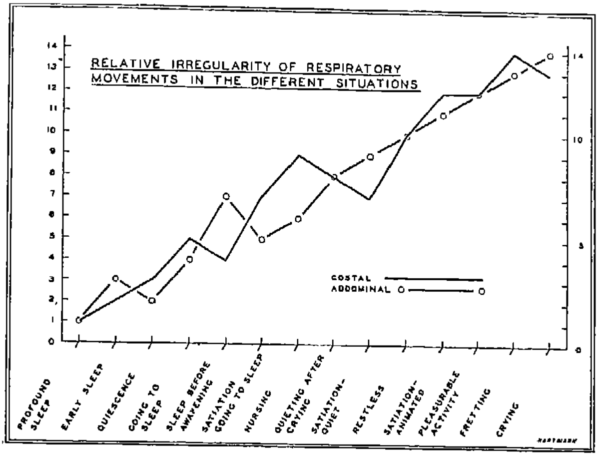

FIGURE 11
Relative Irregularity of Breathing in the Different Situations

(1-14) of the situations in accordance with the combined mean and median measures of the magnitude and number of the irregularities in the breathing curves (Table 1). Costal and abdominal curves are treated separately.

N. Differences in Pulse Rate and Breathing Rate During Sleep

Physiological conditions during the period preceding *Sleep* affect the pulse rate in *Early Sleep*. Of the 41 infants observed during *Early Sleep*, 20 were asleep within 20 minutes after nursing, 8 went to sleep 40-125 minutes after the feeding period following a period

of crying, 11 lay awake for 35-95 minutes after nursing and went to sleep quietly, and two went to sleep within 25-35 minutes after nursing following a period of crying. The pulse and breathing rates of the three larger groups during *Early Sleep* are indicated in Table *B*.

TABLE B

	Age in weeks	Pulse rate	Breathing rate
	Soon after nursing		
Mean	9.6	136.8	44.7
Median	6.5	137.	43.
Range	2-24	126-154	30-66
	After crying		
Mean	7.4	134.0	43.4
Median	4	132.	41.
Range	3-22	124-152	39-51
	After quiet period		
Mean	10.9	123.8	40.2
Median	9.	126.	42.
Range	3-22	114-129	29-51

According to these results pulse and breathing rates were lower for the group of infants who went to sleep quietly between feeding periods than for either of the other groups. Although the number of infants in each of the above groups who attained *Profound Sleep* at this time was materially reduced, their records below indicate that the conditions preceding *Sleep* similarly affect the pulse rate during *Profound Sleep*. Differences in breathing rate between the groups are small (Table *C*).

O. Depth of Sleep

Sleep is frequently differentiated as light or deep. People are said to be sleeping lightly at one time and to be in deep sleep at another time. Some individuals are designated as light sleepers, others as deep sleepers. In most cases judgments of the depth of sleep are based on casual observations during which one notes the depth and regularity of the breathing and the state of quiescence or restlessness of the sleeping person. It is generally believed that the depth of sleep increases during the first hour, then decreases (15). Among the recent studies bearing on the depth of sleep in infants are the experiments by Wagner (59) and Reynard and Dockeray

TABLE C

	Number of cases	Age in weeks	Pulse rate	Breathing rate
		Soon after nursing		
	14			
Mean		12.3	127.2	32.8
Median		5 0	128.5	33.
Range		2-24	109-138	24-38
		After crying		
	4			
Mean		6.5	120 3	32.5
Median		5 5	119.	35.5
Range		4-11	112-131	19-40
		After quiet period		
	5			
Mean		14.6	114.6	34.
Median		17.	112	31.
Range		3-22	106-128	26-42

(50). In both investigations the method of recording the duration and extent of responses to various types of stimulation revealed several stages in depth of sleep. Studies on children appear to indicate that sleep is more quiet after violent exercise and after micturition (17) and becomes deeper with the approach of morning (9). Children are generally restless when their bowels are loose and sleep longer when constipated (17).

P. Brief Characterizations of the Three Stages of Sleep Herein Studied

As a rule, the more quiescent the infant, the more uniform the breathing. The most complete quiescence is that of *Profound Sleep* and it is at this time that respiration is most uniform in time and depth.

Breathing curves are usually very undulatory in *Early Sleep*. In most instances the respirations are very uniform in time and depth. In other instances periodic or irregular fluctuations in depth occur which may or may not affect the rhythm. Occasionally breathing is interrupted by a sigh, prolonged expiration, or momentary suspension of respiration. The relatively high undulations are definitely indicative of the instability of the breathing mechanism. This period, as well as that of *Going to Sleep,* represents a transitional stage between *Waking* and *Profound Sleep*. The infant may at any time

sink into deep sleep, or he may awaken and remain awake or again fall asleep. Pulse and respiratory rates are relatively high.

Profound Sleep is characterized by a low breathing rate, very regular respiration, gentle and very long respiratory undulations or absence of them, a low pulse rate except when sleep immediately follows feeding, and absence of all bodily movements except very infrequent muscular twitches. The duration of the undulations varies from 30 to 60 seconds. Although their presence on the breathing curves is usually apparent to the unaided eye, there are occasions when they can be detected only by means of a straight edge. In any case the rhythm of their occurrence is excessively slow.

Comparison of the individual records of *Profound Sleep* shows that what may be regarded as low pulse or respiratory rates for one infant are actually relatively high rates for another. For example, *M*'s pulse rate in *Profound Sleep* was 128 and his breathing rate was 36; whereas *B*'s pulse rate was 109, and his breathing rate 24. The fact that *M* was older and larger than *B* eliminates the age and size factors in the explanation of the differences in rates.

Breathing during *Sleep before Awakening* is characteristically slow and deep, but only periodically uniform, due to occasional excessively deep inspirations. Pulse and respiratory rates are as low at this time as they are in *Profound Sleep*.

Q. Cheyne-Stokes Breathing

Cheyne-Stokes breathing represents a marked variation in normal breathing. It usually occurs in certain pathological conditions, such as meningitis (8, 39) but may also occur under normal conditions. Respiration in quiet, normal adults is fairly uniform in depth and rate. However, the amplitude of the inspirations may alter rhythmically and thus cause undulations in the breathing pattern. This is particularly true in the instance of very young and elderly individuals (8, 23). According to Greene (23) the undulatory type of breathing frequently presages Cheyne-Stokes respiration. The horizontal position of the body is conducive to periodic breathing (29). Reed and Kleitman (49), for example, noted periodic breathing and other irregularities of respiration in resting adults which disappeared during deep sleep. Furthermore, a resting person can induce an apneic condition followed by periodic respiration by breathing very deeply and fast for two or three minutes (39). In infancy extreme and moderate types of Cheyne-Stokes breathing are both

rather common (12, 39). The extreme type varies greatly in the number and amplitude of the respirations during the dyspneic phase and in the duration of the apneic interval.

A number of investigators (8, 22, 23, 42), have studied undulatory breathing in terms of the expiratory position of the chest and have noted that, whereas its position was in most instances quite constant during quiet breathing of adults, fluctuations in its position also occurred in normal persons (8, 22).

Traube-Hering waves of blood pressure and alterations in pulse rate attend Cheyne-Stokes breathing. According to Eyster (14) patients with nephritis or cardiac failure show a fall in blood pressure and pulse rate during the dyspneic phase and a rise in blood pressure and pulse rate during apnea. The reverse relations hold in the instance of intracranial pressure, viz., blood pressure and pulse rate increase during the dyspneic phase and fall during the apneic interval. Peabody and Wentworth (44) state that the tendency to dyspnea in patients with heart disease is closely associated with a low vital capacity of the lungs.

Cheyne-Stokes breathing occurred in many instances when infants were quiet, especially during sleep. In some cases this type of breathing was not well defined, or it suddenly appeared, continued for several seconds, and as quickly disappeared. However, in 21 instances it was so well marked as to deserve special attention.

Table 4 presents these 21 cases of Cheyne-Stokes breathing and gives certain detailed information concerning their character and the conditions under which they occurred. Altogether 15 infants are represented in the table. Three of the infants, distinguished by the letters *A, B,* and *C* in the age column, experienced Cheyne-Stokes breathing in three different situations during one observation period. Of the 21 samples, six were of the extreme type and contained apneic phases lasting from two to seven seconds. Isolated instances of apnea, not herein recorded, also occurred during sleep. Apnea in all cases began at the end of an abdominal expiratory movement before the corresponding costal movement was well under way. Thus the condition was one in which the abdomen was deflated and the thorax partially inflated. In this connection it should be mentioned that not only does abdominal breathing predominate during sleep, but the lag in the costal movements is greater at this time than in any other situation.

The respiratory rate per minute for the moderate type of Cheyne-

TABLE 4

CONDITIONS OF CHEYNE-STOKES BREATHING

Situation	Age (wks.)	Sex	Moderate or extreme type	Respiration rate	No. phases per min.	No. respirations per phase	Movement of pulse curve: Up on dyspnea	Movement of pulse curve: Up on apnea	Movement of pulse curve: No. movements or irreg.	Preceding conditions	Comments
Quiet—awake	9 *A*	M	Moderate	50	4	6-19			1	Animated	Phases vary in number of respirations
Satiation—quiet	2	M	Moderate	60	7	5- 9			1	Nursing	Sleepy
	13	M	Moderate	98	8	10-14	1			Nursing	
Going to sleep	9 *A*	M	Moderate	44	6	4-10			1	Fretting	Stronger with sleep, then disappears
	24	F	Moderate	46	7	6- 7	1			Nursing	
	22	F	Moderate	48	5	8-10	1			Nursing	Also Traube-Hering pulse waves
	9	F	Moderate	48	6	6- 9	1			Nursing	Also sucking thumb
	5	F	Moderate	45	9	4- 7	1			Fretting and crying	Changes to extreme type in profound sleep
	5 *B*	F	Extreme	43	5	6-11	1			Nursing	One apneic phase of 7 sec. duration
	17 *C*	F	Extreme	61	2	5-41	1			Nursing	One apneic phase of 5 sec. and another of 2 sec.
Early sleep	8	F	Moderate	46	5	6-11	1			Fretting	
	20	F	Moderate	31	3	9-14	1			Nursing	
	6	F	Moderate	44	6	7- 8	1			Fretting and crying	
	9 *A*	M	Moderate	42	7	5- 9	1			Fretting and restless	Disappears with sleep
	23	F	Moderate	40	6	6- 7			1	Nursing	Thorax does not respond on small respiratory movements
Profound sleep	20	F	Extreme	28	4	7- 8		1		Animated and fretting	Apneic phases 2-6 sec. in duration
	5 *B*	F	Extreme	38	5	4- 8	1			Nursing	Apneic phases 2-7 sec in duration
Late sleep before awakening	17 *C*	F	Extreme	47	6	7- 8			1	Deep sleep	Apneic phases 2-3 sec. in duration
	5 *B*	F	Extreme	35	5	4- 8	1			Deep sleep	
	22	M	Moderate	28	7	3- 5	1			Deep sleep	Apneic phases average about 4 sec.
Awakening	17 *C*	F	Moderate	33	4	7-10			1	Light sleep	

Stokes breathing ranged from 28 in *Light Sleep* to 98 in *Satiation-Quiet*. The range for the extreme type was from 28 in *Profound Sleep* to 61 in *Going to Sleep*. The number of dyspneic cycles per minute varied from two to nine and apparently had no connection with the respiratory rate or the conditions preceding or attending Cheyne-Stokes breathing. The number of respirations per cycle for each infant was far from constant, although there were five cases in which the variation from cycle to cycle was only one respiration. In some instances the increase in amplitude of the respirations was accompanied by a quickening of breathing and, on four occasions, respiration during the dyspneic phase was of sufficient force to startle the infant. Rhythmic waves of blood pressure (Traube-Hering waves) showing a rise in pressure coincidental with the dyspneic phase were evidenced in 14 instances. In one instance the increase in blood pressure coincided with the apneic phase, and in six instances the pulse curve was level or its movements too irregular to determine its course with accuracy.

The conditions which preceded Cheyne-Stokes breathing indicate that forced breathing during a period of vigorous bodily activity may in some way have affected the breathing process in the subsequent quiet period. The artificial method of inducing Cheyne-Stokes breathing, applied by Laurens (39), suggests this possibility

Altogether there were five instances of Cheyne-Stokes breathing of the moderate type during the period of awakening. However, in four instances the occurrence of the dyspneic phases and the alterations in amplitude of the respiratoıy movements were so irregular that it seemed advisable not to include them in the table. In all five cases the infants appeared to be hovering between sleep and waking. Waking appeared imminent at each period of dyspneic breathing and less probable in the quiet breathing intervals. Stirring frequently occurred during the dyspneic phase.

R. The Pulse Curve

Records of fontanel tracings show that changes in the behavior of infants are attended by alterations in intracranial pressure. Canestrini (7) for example, found that the brain volume of young infants increased temporarily in response to various types of sensory stimulation, viz., visual, auditory, gustatory, olfactory, and tactile. The responses for the most part varied according to the intensity of the stimuli and the physiological state of the infant. During feeding

each suck was followed by a distinct rise and fall of the fontanel curve which Canestrini ascribed to the momentary venous congestion due to the constriction of the blood vessels. Increases in brain volume also occurred with crying. Rapid fluctuations in intracranial pressure and movements of the head at this time caused the curve to become very irregular. Dilatation of the brain under varying conditions of stimulation also occurs in adults (35).

In the present experiment the roughness of the pulse curve varied directly with the bodily activity. The curve was very smooth, sometimes gently undulatory, during *Sleep* and excessively rough during *Crying*. Vigorous sucking at the beginning of the feeding period resulted in marked head movements and produced a very irregular curve. When the sucking movements became smooth and regular, the curve rose and fell with each suck.

Increase in the pulse rate was usually accompanied by a reduction in the amplitude of the beat. However, in *Quieting after Crying* and in seven instances of *Quiet Awakening,* the pulse beats were unusually strong at first and gradually diminished in amplitude as the infant quieted. In two instances of *Awakening,* the pulse was very rapid and of small amplitude but became slower and more marked with further quieting.

Undulations in the pulse curve occurred in all situations and in most cases paralleled the undulations of the costal curve. In general, the more quiescent the infant, the longer and more gentle the undulations. In some cases of *Profound Sleep* the undulations were so long and flat that, as in the case of the respiratory undulations, their presence could not be detected without the aid of a straight edge.

S. Traube-Hering Waves and Pulse Rhythms

Traube-Hering waves synchronous with the breathing movements were evidenced on numerous occasions when infants were quiet. These respiratory waves of blood pressure occurred most frequently during sleep. The frequency and conditions under which they occurred are indicated in Table 5. When respiration was regular and fairly slow, the waves were very constant in amplitude, length, and number of pulses (usually three) per cycle. When respiration was rapid the number of pulses per wave frequently varied (from three to two) and occasional small irregularities appeared in the curve. The amplitude and length of the waves varied not only with the infants but with the same individual on different occasions.

TABLE 5

Distribution of Pulse Rhythms in Various Situations

Situation	Pulse groups of						Pulse beats per Traube-Hering wave								Total number of groups
	2	2+3	3	3+4	4	4+5	2	3	3+4	4	5	4—6	4—8	5—9	
Quieting after crying		6													6
Nursing			1												1
Satiated—quiet	2						1		1						4
Satiated—going to sleep			2						7				1		10
Early sleep	1			1	1			4	2			3	1		13
Profound sleep	1			1	1	3		2		2	2	2		3	17
Sleep before awakening										1			2		3

Whenever Traube-Hering waves occurred, their amplitude appeared to vary directly with the amplitude of the pulse and inversely with its rate. When the pulse was slow and strong, the waves stood out prominently; when the pulse was very rapid and weak, the waves were tiny. On many occasions the pulse beats occurred in clusters with well-defined rhythms of two, three, or four beats to a group, by virtue of a strong pulse beat followed by one, two, or three weak beats (Table 5). There was usually a slight pause between clusters. Traube-Hering waves much longer than those due to respiratory movements were obtained on two occasions during *Profound Sleep*, following feeding in one case and crying in the other. Breathing was fairly rapid in both cases. As a rule, arterial blood pressure rises with inspiration and falls with expiration. It is believed that these longer waves of blood pressure are due to "a rhythmical change of tone in the vasoconstrictor centre" (35, p. 626).

T. Awakening from Sleep

Awakening is not listed with the other situations because of the great differences between the infants in the duration of this period. Gradual arousal from sleep usually resulted in quiet awakening, whereas sudden awakening generally ended in fretting or crying. The first indication that awakening was about to take place was a marked decrease in the rate and increase in the depth of breathing, or a sudden deep inflation followed by quickened breathing. The thorax and abdomen were then elevated and a period of mixed deep and shallow breathing occurred, during which the respiratory curves pursued a very erratic course. In *Quiet Awakening* the arches gradually resolved into gentle undulations of varying lengths and the respirations became more uniform in duration and depth. The respiratory rate is not only higher after awakening than during sleep, but breathing occurs at a higher elevation of the thorax and abdomen.

Movements of head, hands, and legs corresponded closely with respiratory movements in frequency and scope. The higher the respiratory rate and the deeper the breathing, the greater the frequency and the magnitude of the movements of the head and extremities. In this connection it was noted that deep inhalations were always attended by sharp flexion of the legs and hands, indicative of an increase in tension of the musculature of the body; whereas exhalations were accompanied by relaxation or extension of these

parts. Opening the eyes usually occurred with the first of a succession of very deep inspirations. The scope and irregularity of the respiratory movements and the duration of the period of awakening serve as a barometer of the difficulty of adjustment from sleep to waking.

The mean amplitude of both costal and abdominal movements was greater during the process of *Quiet Awakening* than in any other situation, with the exception of the costal movements in *Nursing* (compare Tables 1 and 6). The respiratory waves *before Awakening* were the same as those of *Profound Sleep*. After awakening, the costal waves were of the Hill and Dale or Skewed Hill and Dale type. The abdominal waves were of the Skewed Hill and Dale Type, sometimes slightly cusped. In one instance Cheyne-Stokes breathing of the moderate type preceded awakening.

The following description is a brief account of the course of the breathing during *Quiet Awakening* of a girl of five weeks. The breathing suddenly became deeper, slower, and somewhat irregular. This was followed by elevation of the thorax and abdomen, which raised the respiratory level, and by steady deep breathing. Next the thorax and abdomen were gradually lowered, then elevated, and respiration became faster and more irregular. There were alternate periods of deep and shallow breathing and finally a deep inflation of the lungs, on which the eyes opened. Additional inflations and a 4-second interval of holding the breath completely aroused the infant. Breathing gradually became slower and more regular but its rate continued higher than the sleeping rate.

Altogether 18 records of *Awakening* were obtained, 9 of *Quiet Awakening*, 5 in which infants started to fret, and 4 in which they cried. The measures relating to pulse and breathing before, during, and after awakening are presented in Table 6. The records in all cases were continuous, starting with sleep and ending two minutes after the opening of the eyes. The *Asleep* record covered 15 seconds. The period of opening eyes began 10 seconds before the eyes opened and continued 20 seconds. The *Awake* record began 30 seconds after the eyes opened and lasted 30 seconds.

The records show a rapid increase in pulse rate from sleep to opening of the eyes for all three conditions. This is followed by a reduction in pulse rate in *Quiet Awakening* (12-13 beats) and in *Fretting*, and by a further increase in pulse frequency in *Crying*. Breathing rates in all cases are much higher after *Awakening* than

TABLE 6

Pulse Rate, Breathing Rate, and Measures of Various Aspects of the Breathing Curves during *Quiet Awakening, Awakening and Fretting*, and *Awakening and Crying*

Number of infants	Conditions of awakening		Pulse rate Mean	Pulse rate Med.	Pulse rate Range	Breathing rate Mean	Breathing rate Med.	Breathing rate Range	Mean amplitude of individual respiratory movements (mm.) Mean	Med.	Range	Maximum height of curve (mm.) Mean	Med.	Range	Number of undulations per minute Mean	Med.	Range	
9	Quiet	Asleep	125.6	126	106-137	39.9	37	30-60	3.6	3	2-6	6.4	7	3-10	2.6	3	1-5	Costal
									7.5	8	6-9	11	10	8-15	2 9	4	1-4	Abdominal
		Opens eyes	148.4	144	128-172				3.6	3	2-6	36.2	34	7-65	12.0	14	3-20	Costal
		Awake	134.9	132	123-152	63.1	56	45-86	6.3	6	3-10	37.9	36	14-54	11	11	3-28	Abdominal
5	Fretting	Asleep	124.6	127	107-132	35.8	34	30-47	4	4	3-5	5.4	5	4-7	2.6	2	1-6	Costal
									7	7	6-9	9.8	9	8-13	1.8	2	1-2	Abdominal
		Opens eyes	157.8	156	140-176							32	33	19-42	22	19	6-48	Costal
		Awake	141.2	143	128-152	87.4	88	73-102				48.6	54	26-63	18.2	13	4-39	Abdominal
4	Crying	Asleep	130.8	132	121-138	32.5	32	24-42	3.3	3	3-4	4.8	5	4-5	1	1	0-2	Costal
									7	6.5	6-9	8.8	8.5	8-10	1	0.5	0-3	Abdominal
		Opens eyes	148	148	140-156							38	35.5	24-57	15	9.5	5-36	Costal
		Awake	178	179.5	170-183	98.8	98	89-110				57	55.5	45-72	12.5	8	6-28	Abdominal

in *Sleep*, and much higher for *Fretting* and *Crying* than for *Quiet Awakening*. The increase in the latter case is about 20 respirations per minute. There is no marked difference between the amplitudes of the costal movements or between the amplitudes of the abdominal movements during *Sleep* in the three situations. The amplitude of the respiratory movements during *Fretting* and *Crying* could not be accurately determined. In *Quiet Awakening*, however, the abdominal movements are somewhat smaller after awakening than in *Sleep*; whereas the costal movements are of the same amplitude before and after awakening.

The maximum height of the breathing waves is very much greater after *Awakening* than in *Sleep*. The curves gradually descend during *Quiet Awakening* but remain at a high level during *Fretting* and even increase in height during *Crying*. Undulations are not only more numerous after *Awakening* than befoıe *Awakening*, but they are much higher and of the arched type. There are more undulations during *Fretting* than during *Quiet Awakening* or *Crying*, but the crying undulations are more abrupt and rugged and contain numerous minor undulations.

U. Micturition and Defecation

Boas and Goldschmidt (3) found that in most instances the heart rate was not affected by micturition or defecation. In some instances there was a slight acceleration in rate with micturition and an initial drop in rate followed by a slight increase with defecation.

Three records of micturition were obtained, two after nursing and one on awakening. The records weıe similar with respect to the gross aspects of behavior. The act of voiding the bladder was in all cases anticipated by a sudden change in the breathing pattern and in the movements of the legs. The infants were moving quietly when the thorax and abdomen were abruptly elevated and then lowered, after which there was a period of rather uniform breathing. This behavior was repeated from thıee to five times. Then the thorax and abdomen were again elevated and lowered and micturition took place. During micturition the abdomen (and in one case, the thorax) gradually contracted although breathing was fairly uniform. On all occasions elevation of the abdomen was attended by a corresponding elevation and flexion of the legs, while contraction of the thorax and abdomen was accompanied by loweıing of

the legs. The legs were usually very quiet during periods of regular breathing. Gripping pressure was variable and steady in turn. However, the hands tightened perceptibly during the quiet period preceding micturition and remained tightly closed during and immediately after this act, but not without some alterations in tension (see Figure 12).

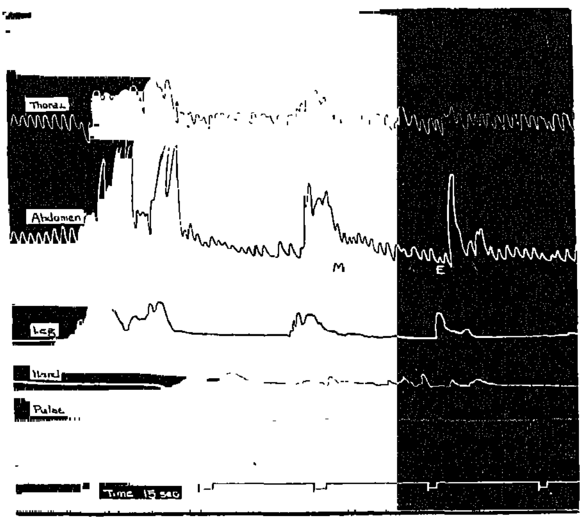

FIGURE 12

MICTURITION

Micturition began at *M* and ended at *E*. Note that both abdomen and thorax contracted during the act, and that the abdomen also contracted during the quiet period preceding the act. The legs were raised and then lowered before the bladder released its contents. Gripping pressure varied during the act and became more irregular near the end.

The preparatory period in the three cases varied from 20 to 105 seconds. The quiet periods of uniform breathing varied from 8 to 20 seconds. Respiration quickened and became very irregular with the elevation of thorax and abdomen and decelerated after they were lowered.

The pulse and breathing rates were as indicated in Table *D*.

The breathing rate in general was affected but little by the act of urination. The pulse in two instances became stronger and

TABLE D

Infant	Age in weeks	Time of act	Breathing rate Before act	Breathing rate During act	Pulse rate Before act	Pulse rate At start	Pulse rate During act
A	9	After nursing	93	95	140	156	144
B	7	After nursing	62	63	136	147	135
C	4	On awakening	63	64	126	126	126

irregular just before micturition took place. The rate increased as voiding began but quickly diminished during and after the act. In the case of the third infant, micturition occurred without any perceptible change in the pulse and breathing rates.

There was one record of defecation. The act was immediately preceded by two very deep prolonged inflations. Then came a deep inspiration after which the breath was held for six seconds as the act began. Expiration then occurred and another deep respiration was followed by 17 small, fast, and irregular respirations. The entire act lasted about 13 seconds. The breathing rate before defecation was 51. The rate for the 17 small respirations was 70. The legs were raised quickly with each deep inflation and lowered slowly during evacuation. The hands which were closed throughout were clenched tightly two times during the act. The pulse rate taken at intervals of 15 seconds varied from 126-132.

V. Hiccoughs

Hiccoughing occurred during and after feeding, after awakening, and after a period of prolonged crying. The intervals between spasms varied considerably. Judging from the breathing which was very similar to that of quiescence, except for the abrupt interruptions by the hiccoughs, the latter apparently occasioned little annoyance. The records indicate that a hiccough may occur during any phase of the respiratory cycle (Figure 1, Type 1, *F*) and that its duration is less than one second. It is represented on the breathing curves by opposed spikes, i.e., the abdomen moves up and down as the thorax moves down and up.

The records of 10 cases of hiccoughing showing the number of hiccoughs per minute and the variations in pulse and respiratory rates per minute for each of the four 15-second intervals are presented in Table 7. The mean number of hiccoughs per minute was 20.3.

TABLE 7

Number hiccoughs per min.	Variations in pulse rate	Variations in respiratory rate	Conditions under which hiccoughs occurred
22	130-135	46-48	After nursing
21	136-147	52-57	After nursing
16	133-137	57-58	After nursing
19	136-138	55-61	After nursing
23	140-145	64-67	After nursing
14	131-135	43-52	During nursing
21	138-141	41-48	During nursing
22	123-126	42-45	After awakening
20	129-137	56-62	After awakening
25	152-158	71-75	After crying

Hiccoughing apparently had little effect on the pulse and respiratory rates. Pulse rates varied from 2 to 11 beats per minute and breathing rates from 2 to 9 respirations per minute. There was no general increase in pulse rate or breathing rate.

W. Sex Differences in Pulse Rate and Breathing Rate

Results of investigations indicate that the difference between the sexes in pulse rate is small at birth but increases significantly with age. Sontag and Richards (53) state that there is no material difference between the sexes in the heart rate or in its daily variability for the fetus or the newborn infant. Guy (27) asserts that the difference is slight in infancy but becomes marked during childhood. Vierordt, cited by Feldman (15), reports the pulse rate equal for the sexes up to five years; whereas Trousseau, also cited by Feldman (15), finds the rate higher in girls than in boys after the third month. Friberger (57) says that from 6 years to 15 years the heart rate in girls is about 11 beats higher than in boys. According to Guy (27) the frequency for girls under two years was 114 and for boys 110. At 8-12 years the rate was 92 for girls and 79 for boys. Sutliff and Holt (57) state that the average basal rate for females is higher than that of males at all age periods after 10 years. Their records show basal rates of 122 for girls and 116 for boys at one year. Women had a basal rate of 69, men 62. Boas and Goldschmidt's basal rates (3) were 69.9 for women and 61.4 for men. Higher rates for the women were also indicated during both sleep and waking. Thus it appears that the difference between the sexes in heart rate is slight in infancy but increases with age. In this connection Gundobin (15) states that size and not sex as

such is the determining factor in pulse rate. He explains that the male is usually larger than the female and therefore has the slower pulse.

Although much has been written on the subject of sex differences in breathing, no extended discussion of the pros and cons of the proposed differences will be undertaken in this paper. Suffice to say that it has long been held (36) that the breathing mechanism functions differently in men than in women. Howell (35), for example, says that in standing, men normally exhibit the abdominal type of breathing and women the costal type. The difference between the sexes in the manner of dress is ascribed as the principal contributing cause of the difference in breathing. White women wear tight dresses and thus restrict the movements of diaphragm; whereas men, as well as women of other races who breath abdominally, wear loose clothing and thus enjoy free use of the diaphragm and abdomen. Fitz (16), after obtaining over 400 thoracic and abdominal pneumographic tracings from boys, girls, men, and women of various races, concludes that the respiratory movements of boys and girls differ very little in character and that the movements in normal breathing for both sexes are "fairly equally balanced between chest and abdomen." However, he adds that the abdominal movements are slightly greater. The type of respiration apparently changes little from childhood to adulthood. These results, of course, contrast with those of Hutchinson (36) who in the middle of the last century found that costal breathing was present in girls of 11 to 14 years of age who had never worn tight clothing. Sex differences in breathing rate of 27 young infants from birth to 13 weeks are reported by Deming and Washburn (12). The boys who numbered 17 had a mean breathing rate during sleep of 43 respirations per minute; whereas the mean breathing rate for the 10 girls under similar conditions was 36. In addition the 12 most rapid rates were found among the samples of breathing obtained from the boys. It was also found that the tendency toward periodic respiration was relatively greater among the girls than among the boys. Fluctuations in rate and volume, and variations in types of breathing, were observed in nearly all the infants. According to Gregor (24) sex differences in respiration are manifested after 10 years in abdominal breathing by the boys and costal breathing by the girls. On the other hand, Hagemann (28) states that during the

first 12 years of life boys show a tendency toward thoracic breathing while girls tend to breathe abdominally.

1. *Comparison of Pulse and Respiratory Rates of Boys and Girls*

In the present study comparison was made of the pulse rates and respiratory rates of boys and girls in eight situations in which the number of either sex was six or more. The situations are indicated in Table 8. The measures were obtained from the individual mean pulse and respiratory rates of the infants.

TABLE 8
COMPARISON OF PULSE AND BREATHING RATES OF BOYS AND GIRLS IN EIGHT SITUATIONS

Situation	Sex	Number infants	Pulse rate Mean	Median	Range	Breathing rate Mean	Median	Range
Crying	Boys	18	179.5	180.5	162-208	135.1	134.5	103-176
	Girls	17	179.2	176	136-220	131.4	134	97-168
Fretting	Boys	16	153.9	154	141-172	93.8	95.5	66-134
	Girls	12	156.5	156	142-168	103.4	100.5	68-146
Pleasurable activity	Boys	6	149.2	147.5	144-156	97	99.5	80-110
	Girls	12	151	151	132-168	89.1	92	70-100
Satiation—animated	Boys	10	153.5	153	146-162	96.6	96	82-112
	Girls	11	151.9	153	135-170	101.9	102	74-122
Satiation—quiet	Boys	10	145.9	142.5	136-160	73.3	72.5	50-104
	Girls	9	147.3	143	141-164	74.7	75	56-92
Going to sleep	Boys	8	135.3	134	122-150	47.4	44.5	34-62
	Girls	15	131.6	132	117-152	47.9	48	37-67
Early sleep	Boys	16	127.9	128	114-140	40.1	40.5	28-54
	Girls	25	132.2	136	120-154	44	43	30-66
Profound sleep	Boys	8	116.3	113.5	106-131	31.1	32	24-36
	Girls	23	126	128	112-138	34.9	36	19-44

Comparison of the mean and median measures shows slightly lower pulse and breathing rates for the boys in the majority of the situations. There is no significant difference between the sexes in pulse rate or in respiratory rate during *Crying* wherein the rates are highest. The situation which offers the most reliable basis for comparison is *Profound Sleep*. In this situation wherein the amount and variability of bodily activity is reduced to a minimum, the boys have a significantly lower pulse rate (about 10 beats) and a correspondingly lower breathing rate (about 4 respirations) than have the girls. Furthermore, 6 of the 8 boys, but only 6 of the 23

girls, have pulse rates lower than the total mean pulse rate for *Profound Sleep;* and 5 of the boys, but only 8 of the girls, have respiratory rates lower than the total mean respiratory rate. These differences in pulse and breathing rates are also manifested in *Early Sleep.*

Eight boys and 15 girls were subjects in both the *Crying* and the *Profound Sleep* situations. When their scores in these situations were compared, the results were virtually the same as those for the entire group (see Table 9).

TABLE 9

COMPARISON OF PULSE AND RESPIRATORY RATES OF EIGHT BOYS AND FIFTEEN GIRLS IN THE *Crying* AND THE *Profound Sleep* SITUATIONS

		Pulse rate per min.		Respiratory rate per min	
		Crying	Asleep	Crying	Asleep
Boys	Mean	181	116.3	133.4	31 1
	Median	175.5	113.5	130.5	32.
	Range	162-208	106-131	103-176	24-36
Girls	Mean	178 9	125.2	129.8	34 6
	Median	175 5	124.5	132.5	37.5
	Range	136-214	112-132	97-168	19-45

X. SIZE AND PULSE RATE

Heart rate varies inversely with size for people in general. Whether or not the relationship holds for individuals of the same age has not been definitely determined. However, Howell (35) asserts that the pulse rate is lower for tall persons than for short persons of the same age, and states that some observers believe that the relationship between pulse rate and size is constant. Feldman (15) presents a table in which year-by-year comparisons show a decrease in pulse frequency with body length. The most one can say in this instance is that pulse frequency is a function of size when it is at the same time a function of age. Sontag and Richards (53) report that, contrary to the generally accepted rule, the heavier and longer infants at birth have a somewhat higher heart rate than do the smaller infants. Harris and Benedict (3) find no connection between body weight and pulse rate, and Boas (3) concludes that evidence of any such relationship is inconclusive.

In the present study, comparison of the pulse rates in *Profound Sleep* with the weights of the subjects fails to confirm the view that

the pulse rate varies inversely with size. (Rank difference coefficient of correlation: $-.15 \pm .15$.) For example, although the lowest pulse rate was registered by the largest of the 31 infants, the second highest pulse rate was that of the second largest infant. There was also no correspondence between weight and breathing rate. In fact, the lowest breathing rate (19 respirations per minute) was registered by one of the three smallest infants.

1. *Comparison of Pulse Rates and Respiratory Rates of the Largest and Smallest Subjects of Each Sex*

Table 10 presents the mean pulse and respiratory rates of four infants in each of three situations in which all were observed. Subject *A* was the largest boy; *B*, the smallest boy; *C*, the largest girl; and *D* the smallest girl, at birth and also at the time of the experiment. The *Profound Sleep* situation, as already stated, probably offers the best basis for comparison of the pulse and respiratory rates. The evidence from this situation, slight as it is in these extreme cases, shows that, whereas the largest subject of each sex has the lower pulse rate, the difference in each case is small. However, it will be noted that the pulse rate of the smallest boy is lower than that of the largest girl. As for respiration, whereas the breathing rate was much lower for the largest boy than for the smallest boy, the conditions were reversed in the instance of the girls. In fact the breathing rate of the smallest girl is almost as low as that of the largest boy. Inasmuch as both pulse and respiratory rates depend to a great degree on bodily activity, the amount of which varies greatly in situations such as *Crying* and *Nursing*, the measures for *Crying* and *Satiation-Animated* are not as reliable as those for *Profound Sleep*. In general, the evidence from the infants as a whole and from these extreme cases does not appear to support the view that larger individuals have lower pulse rates. Neither can it be said that they have lower breathing rates.

Y. Individual Differences

It is evident from the range of the measures in the several tables that there were marked individual differences in pulse rate, breathing rate, and amplitude of the respiratory movements. These differences were clearly shown in *Profound Sleep*, and in general were as conspicuously demonstrated in quiet situations. A second investigation

TABLE 10

MEAN PULSE AND RESPIRATORY RATES OF THE LARGEST AND SMALLEST INFANTS OF EACH SEX

			Weight		Pulse rate			Respiratory rate		
Infant	Sex	Age wks.	at birth lb.—oz.	at time experiment lb.—oz.	Profound sleep	Satiation quiet	Crying	Profound sleep	Satiation quiet	Crying
A	M	6	9 — 2	11 — 3	109	139	184	24	71	122
B	M	5	5 —14	7 — 1	112	140	180	35	61	176
C	F	4	8 — 0	9 — 5	119	164	185	40	85	168
D	F	6	5 — 7	7 — 3	123	142	170	28	78	116

in which infants are studied at intervals of four weeks throughout the first year of life will deal at length with this subject.

Z. Summary and Conclusions

1. The present study indicates that the physiological state of the infant is reflected by his breathing. Comparison of the respiratory curves reveals that each type of behavior represented in the various situations has its characteristic breathing pattern. Differences between patterns are due to modifications in the rate and depth of breathing and to alterations in the inspiratory and expiratory positions of the chest and abdomen.

2. Four types of breathing are exhibited. In the abdominal type inspiratory and expiratory movements are both initiated by the abdomen. In the costal type the movements begin with the chest and spread to the abdomen. In unisonal breathing the corresponding movements of chest and abdomen are synchronized. The exclusively costal type is characterized by antagonistic movements of chest and abdomen. Inspiration is effected by expansion of the chest and contraction of the abdomen. On expiration the conditions are reversed, that is, the chest contracts as the abdominal muscles relax. The abdominal type of breathing prevails during quiescence and sleep when respiration is relatively slow. Inspiration in these situations is usually much faster than expiration. The costal type and unisonal breathing predominate in the moderately exciting situations. Increase in excitement is usually attended by unisonal breathing which later is succeeded by exclusively costal breathing as excitement reaches a climax. Inspiration and expiration are both very rapid and vary greatly in duration and amplitude. Abatement of excitement is attended first by unisonal breathing, in which inspiration and expiration are rapid and of about equal duration, and later by abdominal breathing. Unisonal breathing also occurs during *Satiation,* following vigorous sucking. The exclusively costal type is frequently exhibited during sucking.

3. The thorax expands as excitement increases and contracts as it abates. The more intense the excitement, the greater the expansion; and the greater the duration of the excitement, the more prolonged the expansion. The abdomen also expands as the excitement rises and then contracts and expands violently and intermittently stiffens as breathing becomes exclusively costal. As the ex-

citement abates and breathing becomes unisonal, the movements are smaller and less violent.

4. The ratio of the amplitude of the costal movements to the amplitude of the abdominal movements is greater during excitement and *Nursing* than during *Quiescence* and sleep. Costal mean amplitudes are maximum during *Nursing* and *Pleasurable Activity* and minimum during *Restlessness, Quiescence,* and *Satiation.* The mean amplitude of the abdominal movements is greatest during *Profound Sleep* and *Sleep before Awakening* and smallest during *Satiation-Animated* and *Quieting after Crying.*

5. The pulse rate increases and the respiratory rate decreases during *Nursing.* Both pulse and respiratory rates are higher after *Nursing* than before *Nursing.*

6. The measures obtained from the breathing curves (Table 1) show that alterations in the rate and depth of breathing and in the inspiratory and expiratory positions of the chest and abdomen increase from sleep to waking and from *Quiescence* to intense excitement. The number and degree of the alterations are minimum in *Profound Sleep* and maximum during *Crying.*

7. The expiratory position of the chest is higher during waking than during sleep, and higher during excitement than during *Quiescence.* The expiratory position of the abdomen is only slightly higher during waking than during sleep, and also tends to be higher, despite frequent low dips, during excitement than during *Quiescence.*

8. The more quiescent the infant, the slower and more uniform the breathing and the greater the lag between the corresponding abdominal and costal respiratory movements. In *Profound Sleep* the lag is frequently so marked that the abdominal inspiratory movement is almost completed before the costal inspiratory movement starts.

9. There is no pause between respirations during waking and usually none during sleep, except in extreme types of Cheyne-Stokes breathing.

10. The results of the present study indicate that there is no normal pulse rate or breathing rate for infants as a whole or for the individual infant.

11. The high "frequency, irregularity and easy irritability of the pulse" in early infancy raises the question as to the completeness of the development of the inhibitory apparatus.

12. The range, both of pulse rate and of respiratory rate, during

the normal activities of the infant is considerable but not surprising in view of the fact that crying and sleeping are both very common. The difference between the mean rates for *Crying* and for *Sleep before Awakening* is 55.8 pulse beats and 100.4 respirations per minute.

13. The number of head, hand, and leg movements increases as the irregularities in breathing increase. The greatest number of movements occur during *Crying*, the smallest number during *Profound Sleep*.

14. There is close correspondence between pulse rate and breathing rate in the different situations. In general, high pulse rates are attended by high breathing rates, and low pulse rates by low breathing rates. The rates are higher in waking than in sleep, and higher during excitement than during *Quiescence*. In *Nursing* the pulse rate is relatively high and the breathing rate relatively low. However, the breathing rate after *Nursing* is proportionately as high as the pulse rate.

15. Pulse rates and breathing rates increase with excitement and diminish with *Quiescence* and sleep. Inasmuch as muscular activity also increases with excitement, the high pulse and breathing rates registered at this time are probably due in part to the increase in bodily activity.

16. The highest pulse and breathing rates occur during *Crying*, the lowest during *Profound Sleep* and *Sleep before Awakening*. The longer the sleep, the lower the mean and minimum pulse and breathing rates.

17. Fluctuations in pulse rate are constant during waking. The range of the rate is greatest during *Crying* and least during *Profound Sleep*. Breathing is also irregular during waking, except for short intervals. As a rule, irregularities in breathing and fluctuations in pulse rate are coincidental. The greater the irregularity of the breathing, the greater and more numerous the fluctuations of the pulse rate.

18. Moderate and extreme types of Cheyne-Stokes breathing occurred during sleep. The moderate type was also exhibited on three occasions when infants were awake and quiet.

19. Traube-Hering waves and pulse rhythms synchronous with the breathing movements occurred on numerous occasions during waking and sleep. In two instances of *Profound Sleep*, the waves were longer than the respiratory movements.

20. In the three cases of micturition the act was preceded by elevation of thorax and abdomen, and followed by contraction of the abdomen during voiding. Although pulse and breathing were slightly irregular, the act had little or no effect on the pulse and breathing rates. In two cases the pulse rate increased just before voiding took place but dropped quickly during the act.

21. Hiccoughing may occur during inspiration or expiration and apparently has little or no effect on the pulse rate or breathing rate. The abdomen moves up and down during the spasm, whereas the thorax moves down and up.

22. The present study fails to show any relation between size and pulse rate, or between size and breathing rate.

23. No relation could be found between age and pulse rate, or between age and breathing rate.

24. Comparison of the mean and median measures shows somewhat lower pulse and breathing rates for the boys than for the girls in the majority of the comparable situations. In *Profound Sleep* the boys had a significantly lower pulse rate and a correspondingly lower breathing rate than had the girls.

25. Records obtained during sleep and during quiet periods of waking reveal individual differences in breathing patterns which will be treated in a future study.

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Clinic of Child Development
Yale University
14 Davenport Avenue
New Haven, Connecticut

The Journal of Genetic Psychology, 1941, 59, 331-357.

SYMBOLIC PERFORMANCE OF RATS IN A DELAYED ALTERNATION PROBLEM*[1]

Department of Psychology, University of Washington

RUTH R. HUNTER[2]

A. THE PROBLEM

The present experiment is essentially one in delayed alternation, employing the single alternation technique as the means of presenting the stimuli to the animals. In this study, a central alley led to two alleys diverging at right angles from it, one the left-hand alley, and the other the right-hand alley. If on one choice the rat took the left alley, he must take the right alley on the next choice, and so on. Each of these alternating runs served as the "stimulus" for the next choice; therefore, the stimuli were intrinsic to the animal, since they consisted of the muscular changes occurring on each run. The animal was delayed between choices, and not allowed to make his next choice until a certain period of time had elapsed.

The main purpose of the experiment was to discover, if possible, the mechanisms used by the white rat enabling him to maintain these stimuli or cues during the delay period, and to make the correct choice on the next alternating run around the problem box. The plan of the experiment was to eliminate all possible cues external to the rat so that each choice would have to be made on the basis of the cues received while making the previous run around the box. The external stimuli to be eliminated were gross bodily orientation, audition, vision, and olfaction. If all such stimuli external to the rat could be eliminated, it was then planned that an attempt would be made to eliminate any existing minimal proprioceptive cues in the form of implicit muscular tensions. These might result from the previous choice of the animal, and might aid in making the next choice.

*Received in the Editorial Office on July 3, 1940

[1]This article is the condensation of an M.S. thesis, which is shelved in the University of Washington Library under the title *Delayed Alternation in Rats*.

[2]The writer wishes to express her appreciation to Professor Roger Brown Loucks, whose advice proved invaluable in this study.

If all of these above factors could be removed, the conclusion would be that the rat is able to learn a form of delayed reaction on the basis of cues present in the central nervous system, rather than on the basis of stimuli present in the environment or on the basis of either overt or minimal bodily changes. Thus the animals' behavior would be symbolic, since these neural traces in the central nervous system would serve as substitutes for the stimuli. Such an experiment as this should be able to clarify some of the mechanisms employed in learning, which often consist in reactions made in the absence of the original stimulus for those reactions.

As to the exact nature of neural traces in the central nervous system, speculation at the present time is difficult. It is important, however, to have located the bodily location of such symbols for acts that have not yet taken place. Often humans may not have to resort to such neural traces for their delayed reactions, for the stimulating conditions are such that they may serve directly as symbols for the act. It is interesting to find, however, that acts can be carried out in the absence of cues from the external environment.

B. History of the Problem

Carr was the originator of both the delayed reaction and the alternation techniques. Hunter (6) was the first experimenter actually to utilize the delayed reaction technique. While using a three-choice apparatus, Hunter found that his rats could delay for 10 seconds, but only on the basis of maintaining gross bodily orientation during the delay period. Carr (1, 2), in combining the delayed reaction technique with single alternation, found that a 10-second interval was the best for mastery of the problem, and that rate and accuracy of learning decreased after a delay of 35 seconds was reached.

Apparently no more work was done on the delayed reaction with rats until 1929, when Maier (8) conducted an experiment in which the rats were trained to climb one of three ringstands to get food, and then, after a delay period, to climb the same ringstand. Maier believed that since the rats were placed out of sight of the apparatus during the delay period, gross motor attitudes were ruled out. He obtained delays as long as 24 hours with this procedure. It seems to the present writer that Maier's experiment is not comparable to other delayed reaction studies, since the rats were apparently not

trained to make a number of choices each day. Therefore, this technique would probably be much easier for the rats to master which would account for the extremely long delays which were obtained.

Loucks (7) carried out an experiment very similar to the present one while studying cerebral localization in rats. Loucks obtained delays of four to five minutes with his technique of combining single alternation with delayed reaction, and believed that this was not the limit of the rats' capacity. Gross bodily orientation was seemingly ruled out, and implicit muscle patterns weie somewhat improbable, for two of his ıats were anaesthetized with ethyl chloride during the delay periods, and both gave consistently accurate performances over a period of three days. Although the evidence obtained with these two rats is not conclusive by any means, it is indicative that central cues were being utilized by the rats to bridge the gap during the delay period.

In 1931, Honzik (5) obtained a delay of 45 seconds with his ıats while using a thıee-choice apparatus. The differential stimulus in this expeıiment was the color of curtain on the three doors.

A year later McAllister (9) used visual (light), auditory (bell), and kinaesthetic (going up an incline) stimuli in training his rats in delayed reaction. The animals were kept in motion during the delay period by having them dig through sand, which activity should make it difficult for the rats to maintain any muscular tensions. McAllister concluded that some animals reacted on the basis of intra-organic cues.

Wilson (13, 14) carried out two studies on delayed reaction. During the delay period the rats were required to run down an alley, so that no gross bodily orientation could be maintained. Wilson found that accuıacy of choice decreased with a longer alley and with a longer delay period.

McCord (10, 11) also conducted two investigations of the delayed reaction problem. In using a four-choice apparatus, he found that the rats were able to delay for as long as six to eight minutes, although the highest per cent of correct choices was made at a delay of 60 seconds. McCord believes that this field is central in nature rather than peripheral.

It is obvious that the results obtained in these experiments are extremely variable. The obvious inteıpretation is that these differ-

ences in results must be due to differences in apparatus and technique, or possibly to differences in rats. Only one thing is certain: rats are able to learn a delayed reaction problem. The majority of experimenters agree that gross bodily orientation is not necessary. Implicit muscular tensions as a possible cue have not definitely been ruled out as yet. It is the purpose of the present experiment to throw light on that phase of the problem.

Objections have been raised as to the use of the term "central cues." If the cues utilized by the rat in mastering such a problem as this are not peripheral, they must be "central." As to the exact nature of "central cues," however, no conclusions can be advanced at the present time. The present experimenter believes that if all the other possible cues used by the animals can be successfully eliminated, it may be concluded that the rats are reacting on the basis of neural traces in the central nervous system, and that some contribution has then been made to the field of learning. Only further experimentation will be able to reveal the exact nature of these central neural traces.

C. Apparatus

In Figures 1 and 2 are seen the floor plans of the two types of apparatus used in this experiment. There were vertical screens at the front and at the rear of the wooden problem boxes. The front screen had a small observation window, through which the experimenter could watch the animals. Shields were constructed around the Doors D_2, D_3, D_5, and D_6, so that it was impossible for the animal to see whether the doors were opened or shut until reaching the corner of the box.

The symbol "*F*" in the floor plans indicates the opening of the food gun nozzle inside the delay box. This food gun was a common automobile "grease gun," which was clamped under the table on which the problem box was mounted. Its nozzle protruded through a hole in the floor of the delay box. Turning the handle of the food gun squeezed a small cylinder of food from the nozzle. The food was a dry mash, mixed with enough water to give it the consistency of paste.

The tops of the runways, which were three inches from the floor of the box, were enclosed by means of ½-inch wire screening. The delay box had a glass top, so that it could be made air-tight when

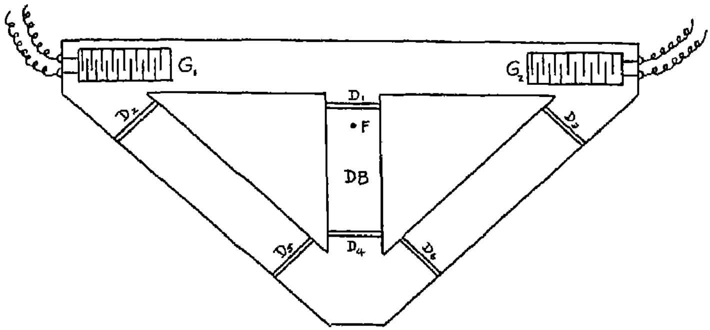
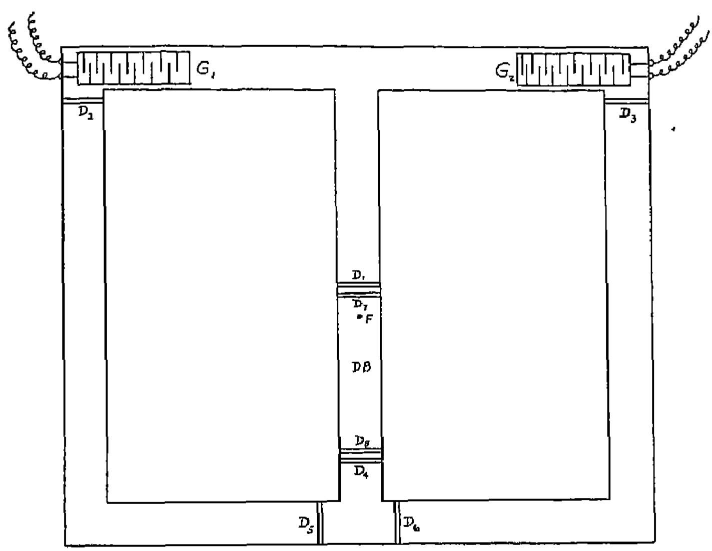


FIGURE 1



Scale .1" = 1"

FIGURE 2

D_1, D_2, D_3, D_4, D_5, D_6, D_7, D_8 — Doors
F — Nozzle of food gun
DB — Delay and food box
G_1, G_2 — Electric grills

an anaesthetic was administered. In administering this anaesthetic, a 100-gram glass container of liquid ethyl chloride was fastened to the front screen. It was connected to a needle valve, from which ran a glass tube into a small opening made in the side of the delay box.

Levers on the experimenter's side of the screen operated the doors. One lever controlled Doors D_1 and D_4; and the other lever controlled the other doors in such a way that Doors D_2 and D_5 were operated together, both of them being either closed or opened at the same time, and likewise with Doors D_3 and D_6.

Doors D_7 and D_8 were inserted in the delay box itself, in contrast to Doors D_1 and D_4, which were inserted in the runway on either side of the delay box. Doors D_7 and D_8 were operated by means of a switch governing two magnets, which were connected to four dry cells. It was not advisable to operate these two doors by means of a lever and cords, since that would hinder removal of the delay box from the apparatus. These doors were used during the problems involving rotation of the delay box by means of a small electrical motor which was mounted underneath the table. Pressing of a button on the outside of the screen turned on the motor, which rotated the delay box by means of a revolving metal shaft projecting up through the floor of the box, and which fitted into a socket on the bottom of the delay box. The speed of the motor could be progressively adjusted from slow to fast.

All maneuvers of the animals in the problem box were timed by the experimenter by means of a stop watch.

The grills were attached to the secondary of a "step-down" transformer, a bell transformer with its connections reversed. The voltage of the grills could be varied according to the rat's sensitivity by means of a potentiometer in the new primary of this reversed bell transformer. A 30-watt light was used to limit the current to the primary. Shutting of Doors D_2 and D_5 turned on Grill G_1, and vice versa.

D. Procedure

The rats were carried in a box from the living cage into the adjacent experimental room for the daily runs. Each rat was given 10 runs daily. For the greater part of the experiment, the rats were run seven days a week, but occasionally there was a lapse of from one to three days. The experiment was begun in October,

1938, and was terminated in May, 1940. Before the beginning of the experiment proper, the rats were allowed to explore the box and to feed in it for a few days.

The daily procedure in running the rats was as follows: The rat was placed in the delay box, which was removable from the problem box as a whole, and was then carried over to the problem box by the experimenter, who placed the delay box in its place. The Door D_1 (also Door D_7, if the problem being used necessitated its use) was opened. The rat would immediately run into the alley leading to the choice point. On the first of the 10 daily trials, the rats were given a free choice of their turns. If a rat turned right on the first run, he must turn left on the next run, and then continue to alternate for the rest of the trials. Door D_1 was immediately closed, to prevent retracing, and Door D_4 was opened, during the time that the rat was running around the box. Upon getting back to the delay box, the rat was allowed to eat a small amount of food which had been squeezed through the food gun while the run was being made. During the delay period various distractions, which will be fully explained, were introduced, and the position of the Doors D_2, D_3, D_5, and D_6 were reversed. After the delay period was over, the rat was again released. If a wrong turn was made, the rat was blocked both by a closed door on that side of the alley and by a charge on the electric grill. It was impossible for the rats to see the door at the end of the alley until they had actually reached the turn at Door D_2 or D_3, for the shields placed around the doors completely hid them both when opened and when closed. At the end of the 10 trials for the day, a large amount of food was squeezed into the delay box, to assure a full diet for the animals. Occasionally a different kind of food was given to them in the living cage, in order to maintain a balanced diet.

The time of the run, and also the time of the delay period, were timed by the experimenter by means of a stop watch. Written records were taken of all times and of errors. An error was considered to be a turn past the choice point such that all of the rat's body except the tail was in the wrong alley. If the rat reversed his decision before turning that far, it was counted as a correct run. If the rat made the wrong turn once, came back to the choice point or to Door D_1, and then made the wrong turn again, it was still counted as just one error. Thus the rat could not make more than

one error on each run. Since the rat was given a free choice on the first run, no errors could be made on that trial. The criterion for mastery of each problem introduced was 90 per cent correct runs over a period of three consecutive days. Thus the rat could not make more than three errors in 30 runs. No more than two errors in any one day were allowed in reaching this criterion. Therefore, three errors on one day and perfect runs on the other two days were not permitted to constitute the criterion. The probability that this criterion could be reached through chance would be 0.00002.

The animals were run at varying times throughout the experiment. For part of the time they were run early in the morning, but most of the time they were run in the late afternoon. The time was kept constant for a period of at least three consecutive weeks, and was changed only when that time proved inconvenient for the experimenter. The experimental room was on the fourth floor of one of the university buildings, and was quite a distance from any classrooms. Therefore, it was comparatively quiet. Any noises or distractions such as other people entering the room, apparently did not disturb the rats at any time.

At the beginning of the experiment, the box shown in Figure 1 was used. After 760 trials for five of the original rats, and 580 trials for the other five, the problem had still not been mastered. Therefore, the problem box seen in Figure 2 was constructed. Four of the rats used in the first apparatus were retained for use in this box, and seven additional rats were introduced. These last 11 rats were the ones retained for the remainder of the experiment. Seven were females, and four males.

Following is a description of the various distractions introduced in order to reduce or eliminate any visual, auditory, olfactory, or proprioceptive cues that the rats might be employing. These were introduced in the order in which they are given below, with the few exceptions which will be explained.

1. *Problem 1: Short Delay*

For this problem all of the 11 rats were employed. After making the first run, the rats were allowed to eat the small cylinder of food, and were released to make the next run as soon as they had finished eating. This delay varied from 5 to 15 seconds, depending upon the length of time that the rat needed for eating the food.

The rats were continued on this problem until they had successfully alternated for 90 per cent of the trials on three consecutive days.

2. *Problem 2: Long Delay*

After making each run, the rats were allowed to eat the standard amount of food. Instead of being released immediately, they were retained for a short time after finishing the food. This proved to be somewhat of a distraction, since the rats would push against the Door D_1, and would often turn around in the box several times. The delay in this case was from 15 to 25 seconds. All of the 11 rats were used for this problem, and were kept on it until they had again reached the criterion.

3. *Problem 3: Lifting*

After the rats had finished eating the food, the experimenter moved from her position behind the screen to the side of the problem box, lifted the delay box out of its place to a position about four inches directly upward, and then replaced it. After this, the door was opened, and the rat was released. The delay period under this condition averaged about 20 seconds. Seven rats were used on this problem.

4. *Problem 4: Turning*

For this problem, six rats were employed. After the rat had finished eating, the experimenter moved from her position behind the screen to the side of the problem box, lifted out the delay box by hand, turned it 180° to the left or right on its vertical axis, and then replaced it. Turning the box to the left or to the right was alternated on successive days, but was kept constant during any one day. The rat was then released for his next run. As on all the other problems, the rats were retained on this problem until they reached the criterion.

5. *Problem 5: Various Turns*

Instead of merely turning the delay box 180° to the left or to the right on its vertical axis, as in Problem 4, it was turned in various ways, in a random order. The box was not turned consistently in one direction throughout the day, but in both ways at random. Furthermore, it was turned from 180° to 720° at various

times. Otherwise, the procedure was the same as that in the preceding problems. Six rats were used for this problem.

6. *Problem 6: Table Turns*

As a check on visual cues resulting from differences in lighting, the table on which the problem box was mounted was provided with casters so that it could readily be moved. The table was moved during the delay period progressively 90° to the left or to the right. The direction was alternated from day to day. Six rats were used.

7. *Problem 7: Longitudinal Rotation*

As a further distraction, the experimenter removed the delay box and rotated it on its longitudinal axis for 360° during each delay period. The rat was allowed to eat the food before being disturbed in this way. This rotation was done by hand, the experimenter making the rotations clockwise one day and counter-clockwise the next, and so on. Since the delay box was considerably larger than the rats, this resulted in their being considerably shaken up. Six rats were used on this problem.

8. *Problem 8: Simple Motor Rotation*

In order to provide a type of rotation which would do away with the experimenter's having to handle the delay box, the motor as described above was installed. It turned the delay box on its vertical axis. The motor could not be reversed, so that the box was always turned clockwise. The speed of the motor was adjusted to its lowest level for this problem, which was 84 180° turns per minute. The delay box was turned only 180°. In addition to the rotation involved, there may have been some distraction from the motor itself, for it made a very discernible noise. During this procedure, the experimenter did not have to move from her position behind the screen. Doors D_7 and D_8 were required on this problem, in order to keep the rat from being thrown out of the delay box during the rotation. These doors were opened and shut by means of magnets which made contact with a metal piece on the top of each door. These magnets were raised and lowered by means of a lever outside the screen. The experimenter soon acquired skill in turning the motor on just long enough to swing the box around 180°. Occasionally it was turned too far, in which case, since the motor was not

reversible, it would have to be continued to 360°. This procedure eliminated any consistent cues given to the rats by the experimenter, except those that might result from the operation of the various levers, since there was no handling of the rats during the actual runs, and since the sound of the motor was relatively constant. Ten rats were used.

9. *Problem 9: Increased Motor Rotation*

The delay box in this procedure was rotated 180° eight to ten times at the same slow speed of the motor used in Problem 8. As soon as the rat had finished eating, the motor was started, and the box was revolved through eight to ten 180° turns on its vertical axis. It was then stopped, the two Doors D_7 and D_1 opened, and the rat was released. Nine rats were used.

10. *Problem 10: Fast Motor Rotation*

The motor was adjusted to its top speed, and was turned on as soon as the rat had finished eating. This speed consisted in 176 180° turns per minute. The delay box was then rotated at this speed for from 14 to 18 180° turns. There was some variability in the number of turns, for the experimenter had some difficulty in turning off the motor at just the proper time during the revolutions, in order to stop the box at the correct position. The speed of the motor was great enough to throw the rat down to one end of the delay box against the door, and to keep the rat there by centrifugal force until the speed slackened. Seven rats were utilized in this procedure.

11. *Problem 11: Shifting Between Two Boxes*

In order to check on olfaction as a cue for the rats, a duplicate box which was constructed as nearly like the one in Figure 2 as possible was used. The rat was started in one of the two problem boxes, and allowed to make one or more runs. Then the rat was lifted (in the delay box) out of that problem box, and placed into the other one, where it was required to make its next run. The doors of the two boxes were so adjusted that they would be in the proper position for that particular run in either box. For example, on one day, the rat might be started out in the original problem box and allowed to make two runs. Then he would be shifted, during the

delay period, to the other box, which was situated about four feet away. The delay box would be placed in the second box, and the rat released to make three more trials. Then he would be returned to the original box to make four runs, and finally back to the second box to make the last run. This order was varied daily. The doors in one box were adjusted while the rat was in the other box. There were from two to six shifts from box to box each day. Five rats were employed on this problem.

12. *Problem 12: Short Delay in Original Triangular Box*

In order to satisfy the curiosity of the experimenter as to the former failure in this box, five of the rats were introduced to the original apparatus shown in Figure 1, which the other rats had failed to master. Three of these five rats had been used originally in this appaiatus. They were put on simple short delay in this box, being ieleased as soon as they had finished eating. No changes had been made in this box except repainting and a better arrangement of cords for opening Doors D_1 and D_4. The procedure in this box was essentially the same as that in the larger box.

13. *Problem 13: Extra Long Delay*

In order to prepare the rats for the anaesthetization which was to follow, a delay of 60 seconds or more was introduced as a separate problem. As soon as the rat completed a run and returned to the delay box, the stop watch was again started; and the rat was retained in the delay box for at least 60 seconds, or in some cases slightly longer. Five animals were used.

14. *Problem 14: Anaesthetic*

In order to start the animals gradually on this problem, the anaesthetic, ethyl chloride, was administered by means of the apparatus described above on the last trial of the day after completion of Problem 13. The next day the animal would be anaesthetized on the last two trials of the day. On the third day ethyl chloride would be used on the last four trials: and after that it would be given on all 10 trials. As soon as the rat had finished eating, the needle valve was opened until the liquid ethyl chloride could be seen running down the glass tubing leading to the opening made in the side of the delay box. The valve was then closed. The Doors D_7

and D_8 were so installed on this delay box (which was a replica of the one used in the foregoing problems as to size and shape) that springs kept them close to the floor of the delay box. In other places, the box was made as nearly air tight as possible, in order to conserve the amount of anaesthetic necessary. The doors were kept closed until the observer saw the rat become perfectly limp and fall to the floor, whereupon these two doors, and, in addition, Door D_1, were opened. Eating took approximately 15 seconds, and anaesthetization took about 30 seconds more. The rat recovered sufficiently to leave the delay box and make his next run in from 15 seconds to 5 minutes after the doors were opened. This time varied according to the concentration of anaesthetic in the box and according to the condition of the animal. It was noticed that toward the end of the day's runs, the effects of the anaesthetic seemed to become cumulative, so that the rat collapsed much more quickly and took a longer time to recover from it. Accordingly, a smaller dose was administered when these effects became noticeable. Three out of the five rats who completed Problem 13 were employed on this problem. It was found with all the rats that this large amount of anaesthetic had bad physiological effects on them. One rat died from the abnormal respiration resulting from it. Accordingly, the anaesthetic was administered either in a random order on only five of the ten trials each day, or else on alternate days. On the trials or the days when the anaesthetic was not used, extra long delay was employed, in order to reinforce the alternation habits of the rat.

E. Controls

In order to make certain that the rats were actually making their choices on the basis of the cues received from the muscular changes occurring on the previous run, it was necessary to eliminate any other cues which might be operating.

To eliminate any cues that the experimenter might be giving the rat directly, the following methods were employed. The experimenter took great care to handle the rat in the same way each day when putting the rat into the delay box. The screen hid all of the experimenter from the view of the rat except the small portion of the face which could be seen through the hole in the screen. Close observation showed that the rats never appeared to look in the direction of the experimenter in making any choices. When the rats

ran toward the choice point, their backs were toward the experimenter, and none of them was ever observed to look back. The use of the motor eliminated the handling of the rats in the delay box during the delay period by the experimenter, so that the possibility of this kind of cue being operative in Problems 3, 4, and 5 was checked. As a final check on this kind of cue being operative, an advanced student in the psychology department took over the handling of the rats for two days. On these days, the experimenter did nothing but operate the stop watch and take the written notes. Since the experimenter gave this student no instructions on how to handle the running of the rats, beyond the information on how to push the levers, this control running was considerably different in procedure from the customary one. Nevertheless, the rats showed no disturbance, and performed in a perfectly normal manner.

Vision was the next cue to be controlled. As mentioned previously, the Doors D_2, D_3, D_5, and D_6 were hidden from view both by the sides of the alleys and by the metal shields placed around them. Thus it was impossible for the rats to tell whether the doors were opened or shut until they had rounded the corner of the alley. The lighting of the experimental room and the objects in the room could give the rat no possible cues, since on one run any particular object would be the cue for turning right, and on the next run this same object would be a cue for turning left. In order to see whether a change in lighting or in the position of the problem box in the room as a whole would make any difference, Probem 6 was introduced. In addition, for a few weeks the table was placed in a new position in the room on each successive day while the rats were on other problems. It was found that such changes made no difference in the performance of the rats. There were no other visual cues that could be operative, except the sight of the experimenter, which has been discussed above.

As an additional check, the experimenter required two rats to obtain the criterion when both slow rotation of the delay box and turning of the table on which the problem box was mounted were being employed. After each rat had made his run, the table was turned progressively 90° to the left or right, and then the delay box was rotated for eight to ten 180° turns by the motor. Thus those cues resulting from vision, from proprioception, and from the experimenter were all controlled at the same time.

The only auditory cues that the rat could receive would be those of the opening and shutting of Doors D_2, D_3, D_5, and D_6. For the greater part of the time, these doors were shifted to the next position just after the rat entered the delay box, during the eating of the food. However, as a check on this, the doors were not changed in some cases until after the rat had made his choice on the next run. After the rat had reached the choice point and had turned one way or the other, the doors were shifted to the proper position, regardless of which way the rat turned. This was not found to alter the behavior of the rat in any way. On other occasions, the doors were shifted in a very slow and noiseless manner, so that even the experimenter could barely detect any noise. This likewise was found to make no difference. As a final check on auditory cues, the doors in one box on Problem 11 were shifted while the rat was in the other box several feet away. The noise of this shift might possibly be heard by the rat, but the chances that the noise could be successfully localized would be very slim indeed, since even the experimenter was unable to tell which doors were being lifted and which were being lowered under these conditions. (Since all four of these doors were operated by a common lever, two of them were going up while the other two were coming down. The noises of the two changes were very similar to each other.) The sound of the motor was uniform on each day, so could not have served as a cue. Any other sounds existing at the time of the daily trials were purely random ones, so could not operate as direct cues.

In order to test the possibility of the rats' receiving any cues from the electric grills, olfactory or otherwise, three of the rats were never given any electrical shocks at any time during the experiment. It was found that these rats were fully as successful as the others. Furthermore, the shock was not employed for at least a total of one month of the time with all the other rats. No change in behavior was noted as resulting from this procedure. The electrical shock was used merely as a punishment reinforcing the closed door on the wrong alley, in the hope that it would facilitate learning. For some rats it proved valuable, but for others it seemed to make no difference, or even to be a distracting factor.

Problem 11 was introduced as a check upon olfaction. The possibility of the rat being able to discriminate between a track 15 seconds old and one 35 seconds old would be exceedingly small,

particularly inasmuch as these two tracks would have to be picked out from hundreds made before that. When the rats happened to pause at the choice point, there was no observable sniffing. Problem 11, however, proved without a doubt that the rat was not making his choices on the basis of olfactory cues. Each run made directly after the shift could not possibly be executed on the basis of the smell of the tracks made on the previous runs. Since the shifting was carried out in a random order, neither could the rat make his choice on the basis of the last run made in that problem box. From time to time the floors of the problem boxes were thoroughly scrubbed so as to remove all tracks. This resulted in no change in behavior of the rats. Since the food was present only in the central delay box, its smell could not aid the rat in any way.

Inasmuch as all these direct cues were successfully eliminated as factors, the experimenter is confident that the only ones that could possibly be utilized by the rats would be those proprioceptive ones received while making each run. These would probably be in the form of tension in the muscles on one side of the body, depending upon whether a right or a left turn had just been made, or in the form of vestibular excitations. Thus the cue for the delayed reaction was one internal to the animal. Problems 2, 3, 4, 5, 7, 8, 9, 10, 13, and 14 were introduced in an attempt to eliminate the residual physical tensions or vestibular excitations that might be maintained on the basis of these cues. Most of the problems were designed to necessitate the moving about of the animal, and the shifting of muscle groups. The procedure employing the anaesthetic was designed as a final check on this, since it involved, as far as could be ascertained, complete relaxation of the rat's body.

F. Results

All of the rats employed on the type of problem box shown in Figure 1 failed to learn the problem of a short delay between trials of alternation. There are several possible explanations for this failure, and for the subsequent success in the apparatus shown in Figure 2. In the first place, the technique of the experimenter may have been faulty at the beginning of the experiment, when the original box was used. The methods of handling the rats, the levers, and other parts of the apparatus may have been awkward and distracting to the rats. The experimenter was not conscious of any

such gradual change in technique from one apparatus to the other, however. It is probable that by the end of 760 trials in the original box, the experimenter's technique should have been rid of any awkwardness which might prove distracting to the rats.

Secondly, there may have been some difference in the physiological condition of the original group of rats, preventing them from learning the problem. Since four of these original rats subsequently learned the problem in the second box, however, it is unlikely that this could have been the cause of the failure in the first box. Furthermore, the diets for the two groups of rats were identical.

Lastly, the explanation for the original failure may have been in the differences between the two problem boxes. The present experimenter has come to this conclusion. In the first box only three sharp turns were necessary for the rat to return to the delay box; whereas in the second box four turns were necessary. This additional turn may have given enough extra cues to the rats to enable them to maintain the alternation tendency during the delay period, whereas the three turns in the original box may not have been sufficient.

Another gross difference between the two boxes may have been the cause of the difference in ease of learning. In the first problem box, the Door D_1 opened directly upon the choice point; whereas in the second box, Door D_1 opened upon an alley 14 inches long leading to the choice point. The run down this 14-inch alley may have aided the rat in orienting himself, in "preparing" himself for the coming choice.

The original problem box was designed as such because the experimenter believed that a smaller apparatus might prove to be more efficient than the larger one in studying this problem. Evidently the rat requires either more turns or an alley leading to the choice point, or both, however, in learning this problem, in order to insure a preparatory constant orientation.

All of the 11 rats used in the larger apparatus learned to alternate when there was a brief delay period between choices. In Table 1 are given the trials required for each rat to learn each of the 14 problems outlined in a previous section of this paper. It is seen that there were great individual differences between the ability of the different rats. The number of trials required to learn the original problem of short delay varied from 40 to 410. It might be

TABLE 1
TRIALS REQUIRED TO LEARN EACH PROBLEM

Problem	#1	#2	#12	#14	#13	#3	#4	#11	#15	#16	#17	Av.	No. rats completing prob	No. rats
Short delay	410	410	400	210	260	170	150	280	310	170	40	255	11	11
Long delay	100	50	30	150	40	250	220	210	370	530	360	210	11	11
Lifting	160	70	50	40	470*	310	250	—	—	—	—	146	6	7
Turning	340	280	40	280	—	430	110	—	—	—	—	246	6	6
Various turns	80	180	220	30	—	200	30	—	—	—	—	123	6	6
Table turns	60	40	120	380	—	70	80	—	—	—	—	125	6	6
Longitud. rotation	90	350	470	170	—	40	190	—	—	—	—	218	6	6
Simple motor rotation	60	90	40	190	—	50	370	740	150	100	780*	199	9	10
Increased motor rotation	520	110	40	820*	—	490	30	170*	330	350	—	267	7	9
Fast motor rotation	110	110	370	—	—	310*	90	—	150	120	—	158	6	7
Shifting	80	310	100	—	—	—	70	—	—	60	—	124	5	5
Original box	150	40	80	—	—	—	170	—	—	440*	—	110	4	5
Extra long delay	290	80	140	—	—	—	300	—	160	—	—	194	5	5
Anaesthetic	149*	130*	202*	—	—	—	—	—	—	—	—	—	0	3

*Rat retained on the problem for this number of trials, then discontinued because of failure to learn problem.

advisable to clarify the point that since 10 trials were given each day, 40 trials would indicate four days which were required to learn the problem, whereas 410 trials would indicate 41 days. Furthermore, these required trials include the 30 trials constituting the attainment of the criterion.

Rats 1, 2, 3, and 4 were those used in the original problem box. Rats 12 and 14 were of different stock, having been obtained from a downtown pet shop. The other rats were laboratory stock. Rats 11, 15, 16, and 17 were males; the rest were females.

Some of the animals were started in the experiment at a later date than the others. This is especially tiue of the four males, who were started about four months after the others. As can be seen in Table 1, Rats 1, 2, and 12 were utilized for all of the 14 problems. Rat 14 was discontinued after a failure to learn increased motor rotation after 820 trials. Rat 13 was discontinued after failure to learn lifting after 470 trials. Rat 3 was used for all of the problems up to fast motor rotation, when it was discontinued after 310 trials. Rat 4 was used for all the problems except the anaesthetic. This rat was discontinued after reaching the criterion on extra long delay. Rat 11 learned short delay and long delay, and was then used immediately for simple motor rotation, without going through the intervening problems. This rat was discontinued while on increased motor rotation. Since only 170 trials had been completed, the rat might have learned this problem if he had been allowed more trials. Rat 15 likewise was not used for the intervening problems between long delay and simple motor rotation, or for shifting and short delay in the original box. It was discontinued from the experiment after reaching the criterion in extra long delay. Rat 16 also skipped the intervening problems, and was discontinued after a failure to learn short delay in the original box. Rat 17 was also not used on the intervening five problems, and was interrupted after failing to learn simple motor rotation.

In the two right-hand columns of Table 1 are given the number of rats used on each problem, and the number of rats reaching the criterion on the problems. The majority of the rats utilized on each problem learned that problem; in fact, in 8 of the 14 problems, all of the rats used attained the criterion, and in the rest of the problems, 80 per cent or more of the rats mastered it.

The column of average trials requiied for each problem indicates

the relative difficulty of each for the rats as a whole, although the great individual differences tend to invalidate this measure of difficulty. It can only be stated tentatively, then, that the easiest problem for the rats was short delay in the original box, and that the hardest problem was increased motor rotation.

Following is a discussion of the significance of the different problems, taken in the order of presentation in Table 1.

The mastery of short delay and of long delay signifies that it is possible for white rats to learn to alternate in this type of apparatus when a delay of from 5 to 25 seconds is interposed between the alternation trials. Therefore, it is possible for rats to maintain the cues for the subsequent reaction at least that length of time.

The next three problems of lifting, turning, and various turns were introduced as a means of upsetting the rat's orientation and muscular tensions. The success of six of the rats in each of these problems indicates that they are able to maintain the necessary mechanisms for subsequent response even while being disoriented. Learning of these problems definitely rules out gross bodily orientation as a means of making a delayed reaction.

The problem of table turns was utilized in order to change the lighting after each choice had been made, in order that the rat could not possibly receive any constant cues from this source. Changing the position of the whole table on which the problem box was mounted threw the shadows cast by the sides of the box and by the closed doors into a different position at the beginning of each trial. Furthermore, the original position of the table at the beginning of each day's trials was changed frequently so that the rats could not learn the sequence of lighting changes. The mastery of this problem by six of the rats indicates that the animals were able to perform delayed reaction without directly depending on visual cues. Changing the position of the table not only altered the lighting, but also altered the position of objects in the room.

Longitudinal rotation tended to shake the rat and to upset any existing muscular tensions much more vigorously than did simple lifting or turning. Since the rat struggled constantly to maintain the normal standing position during the process of rotation, there was considerable bodily activity on his part. The learning of this problem shows definitely that maintenance of a set posture during the delay period is not necessary for the learning of delayed re-

action. It tends to indicate also that minimal muscular tensions are not necessary, for such a vigorous shaking would probably disrupt or disturb such tensions.

The next three problems, in which the electrical motor was utilized, controlled the factor of cues resulting from the experimenter's manipulation of the delay box between trials. Since the speed of the motor was relatively constant on all occasions, it could hardly have served as a cue. The mastery of these three problems, therefore, shows that problems 3, 4, and 5 were valid measures of the ability to delay when bodily postures, and possibly muscular tensions, were eliminated as cues. Fast motor rotation indicated this more substantially than slower rotation, since the speed of the motor was high enough to throw the rats against one of the doors during the time that the motor was running.

The problem involving shifting of the rats from one problem box to a second identical one was planned as a control for both olfaction and audition. Attainment of the criterion by five rats on this problem shows that olfactory cues could not have been operating as a basis for delayed reaction. This problem was designed to eliminate the possibility of the rats' being able to detect the scent of the tracks made on the last trial, and then learning to turn in the opposite direction to the one in which those tracks led. Since in this problem the rats were shifted in an irregular order from one problem box to the other, the operation of any scent as a cue would prove worthless. This problem was also a control for audition, since the doors in one box were changed while the rat was in the other box several feet away.

The experimenter utilized the original box for five of the rats in order to determine whether they could learn delayed alternation in this box after having mastered it in the larger box. Four of the five rats were able to do so. This indicates that learning of the problem in the larger box facilitated in some way the learning of the smaller one. If the difference between the original performances in the two problem boxes was due to their dissimilar construction, it is evident that more turns and/or a central alley leading to the choice point are not necessary once the rat has learned the problem.

Three rats were then anaesthetized during the delay period with ethyl chloride. None of the rats attained the criterion on this problem. There are two possible explanations for this failure. The

first is that the rats were, after all, utilizing proprioceptive cues, and that since anaesthetization destroyed these cues, they were unable to retain the alternation habit. This seems improbable in view of the evidence obtained in the other problems, which, if not actually destroying proprioceptive cues, certainly must have disturbed them severely. The second explanation is that the experimental technique was faulty. When the rats had fallen to the floor and had given all signs of being completely anaesthetized, the Doors D_1, D_7, and D_8 were opened, in order to decrease the concentration of the anaesthetic and to allow the rat to leave the delay box. Usually the rat left the delay box as soon as he had lurched to his feet. Therefore, while making the run around the box, he was still partially under the effect of the anaesthetic. The rats moved in a very stumbling gait, and would often take as long as two minutes to stagger around the box. Inasmuch as the rats did not seem to have good control over their movements, and inasmuch as they would even drop to the floor again while on the way around the box, it seems that the making of correct choices would be difficult, if not impossible, under such physiological conditions. The experimenter believes that this insufficient recovery of the rats from the anaesthetic before making the next choice is responsible for their failure to attain the criterion on this problem. Accordingly, the rats were removed from the problem before being given enough trials to insure their failure to learn it. The success in many of the other problems strongly indicated that proprioceptive cues were not being utilized.

In view of this doubt, however, the experimenter plans to carry out a study during the next academic year in which a new group of rats will first be trained to delay for five minutes between runs, and will then be given the anaesthetic during the delay periods. The same amount of anaesthetic will be given as before, but the rats will not be allowed to leave the delay box to make the next run until five minutes have elapsed, so that they will have considerably recovered from the effects of the anaesthetic. It is believed that when the rats are in a more nearly normal condition while making the choice, they will have more success in alternating. Since the rats in the present experiment showed no signs of having reached a limit when delayed one minute, it is probable that they will be able to delay for five minutes.

TABLE 2
TURNS MADE BY RATS INSIDE DELAY BOX
(Expressed as per cent of total turns)

Rat	No. trials based on	Following choice	Rat turns *L*	Rat turns *R*	Rat turns l-*r*	Rat turns *r*-l	Box turns *L*, Rat turns l	Box turns *L*, Rat turns *r*	Box turns *R*, Rat turns l	Box turns *R*, Rat turns *r*
1	1310	Left	23	12	4	0	27	14	32	4
		Right	36	18	5	2	42	17	56	8
2	1340	Left	8	18	29	2	5	47	31	25
		Right	6	14	22	1	6	42	32	12
12	1200	Left	9	12	22	0	0	44	26	19
		Right	12	19	25	1	15	41	33	22
14	1220	Left	1	37	2	0	0	49	2	47
		Right	1	50	5	4	0	51	1	50
3	1110	Left	14	30	0	0	6	33	10	30
		Right	8	43	4	1	9	52	21	39
4	1030	Left	26	16	0	7	41	2	43	2
		Right	21	19	0	11	57	0	49	6
13	880	Left	10	4	0	17	—	—	—	—
		Right	26	25	9	9	—	—	—	—
All rats	8090	Left	13	19	10	3	12	32	22	23
		Right	14	26	11	4	20	36	31	24

Table 2 shows an analysis of a sampling of the turns made by some of the rats while in the delay box. The experimenter had observed that the rats often turned around toward Door D_4 and then back to Door D_1 during the delay period, and thought that there might be a correlation between the direction of those turns and the direction of the subsequent choice made on the next run. Consequently, the turns made by several of the rats were tabulated. In Table 2 a turn labelled *L* or *R* indicates a 360° turn in one of those two directions. A turn labelled l-*r* or *r*-l indicates that the rat turned to the left 180° in facing Door D_1, and then turned to the right 180° in facing back toward Door D_1, or vice versa. Tabulations were made during several problems. Those made while Problems 4 and 5 were being employed are presented separately in Table 2, in order to see whether this turning of the delay box influenced the turns made by the rat in the delay box. The table shows that there is no direct relationship between the turns made by the rats inside the delay box and the following choice. This lack of correlation indicates that muscular tensions

were not operating, for if they had been present, they probably would have been manifested in the movements of the rats.

One particularly interesting form of behavior was noticed in a few of the rats. After leaving the delay box, they would often proceed as far as the choice point, waver slightly from side to side, then come back to the Door D_1, and finally run down the central alley again to make the choice without hesitation. On a few occasions the rats would, after making an incorrect choice, return to the Door D_1 before proceeding along the correct alley back to the delay box. This type of behavior probably indicates that the run down the central alley served as an aid in orientation for the rats.

It does not seem likely that the rats received any stimuli from the Door D_1, from the central alley, or from the choice point, for if they were relying on such cues, they would not be able to make a correct choice after an incorrect one. When the rats made an incorrect choice, they usually ran directly from the end of that alley, past the choice point, to the open door at the end of the other alley, and then back to the delay box. Each rat therefore had to make the correct turn before getting back to the delay box. If the cues used by the rat were present at some point beyond the turn made at the Door D_2 or D_3, he would be able to make a correct choice on the next trial. Since this was usually the case, the cues received by the rats enabling them to make the next choice must have been operative during that part of the run. The run from the incorrect alley past the choice point would involve an entirely different kind of cue at the choice point for the rats than would a turn at the choice point down the correct alley. Therefore, after making a wrong turn, the rats could not receive the same kind of cue from the choice point as they would if they had made a correct turn in the first place. It would seem from this that if the operative cues were received at the initial turn at the choice point, or from some aspect of that part of the box, a correct run could not be made following an incorrect one. Therefore, it seems probable that the cues received by the rats, which served as the stimuli for the following choice, must have been received while the rats were making the turns subsequent to the one at the choice point. Such cues must be proprioceptive in nature, since the rest of the runways offered no differential cues to the animals.

The only conclusive evidence for the operation of a central neural

trace during the delay period would be the ability of rats to alternate after being through deep narcosis during the delay period. The problems carried out in this study strongly indicate that the cues are central in nature, but do not prove it conclusively. It is improbable that from the activity enforced upon the rats during the delay period, and from the voluntary movements made by the rats when the delay box was not moved during the delay period, that a constant muscular pattern could be maintained over and above such rapid fluctuations of the rat's musculature.

G. Summary

1. A serial alternation box was utilized in a study of delayed reaction. From the construction of the apparatus it was possible for the rats to make successive alternating choices in this two-choice apparatus without the necessity of the experimenter handling them at any time during any one trial. Food was forced into the delay box by means of a "food gun," and was given at the end of each trial.

2. Ten rats failed to learn single alternation, with a short delay period between trials, in the initial type of apparatus used. It is believed that this failure was due to insufficient means of orientation for the rats, to insufficient cues for the rats, or to both of these factors, in this type of problem box.

3. Eleven rats attained the criterion of learning in the second type of problem box used. This proved that the rats were able to maintain the cues received on the last trial in the problem box during a delay period.

4. Several problems were introduced in order to ascertain what type of cue was operative during the delay period. These problems were all eventually learned by the majority of the rats, although each proved to be a distraction to the rats at first. The possibility of visual, auditory, or olfactory cues being operative was eliminated. The success in some of the problems indicates that the proprioceptive cues coming from the kinaesthetic receptors in the muscles, tendons, and joints were not the basis for alternation, since the methods utilized were designed to eliminate or disturb such cues. Gross bodily orientation is definitely ruled out as an explanation of the delayed reactions obtained in the present study.

5. Ethyl chloride was introduced into the delay box during the

delay period for three of the rats. All of these three rats failed to alternate under such conditions. The experimenter believes that this failure was due to an insufficient recovery of the animals from the anaesthetic before making the next choice. A further study is planned in which the rats will be allowed to recover completely from the effects of the ethyl chloride before making the next choice. The writer believes that the rats will be more successful under those conditions.

6. The conclusion of this study is that the white rats in this experiment were probably able to carry out a delayed reaction on the basis of a neural trace in the central nervous system, rather than on the basis of any visual, auditory, olfactory, or proprioceptive cues. The experimenter does not attempt at the present time to describe the exact nature of these central changes.

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Department of Psychology
University of Washington
Seattle, Washington

The Journal of Genetic Psychology, 1941, 59, 359-376.

THE EXTERNALIZATION OF DRIVE: II. THE EFFECT OF SATIATION AND REMOVAL OF REWARD AT DIFFERENT STAGES IN THE LEARNING PROCESS OF THE RAT*

Department of Psychology, Wilson College[1]

E. E. ANDERSON

A. INTRODUCTION

In the first paper of this series (2) it was suggested that the factors important in the arousal of a drive change as the drive is used continually in a relatively constant situation. Specifically it was argued that early in the learning process a drive such as hunger is internally aroused; that is, it is dependent upon physiological conditions produced by the deprivation of food. Later in the learning process the drive mechanism[2] becomes externalized; that is, it is aroused in part by various aspects of the external stimulus situation (the food reward, the food box, the maze itself). On the basis of this theory it was suggested that the removal of the food reward or satiation with food reward present should produce differing effects upon maze performance depending upon the stage of learning at which the conditions were introduced. Early in the learning process the drive is primarily dependent upon internal conditions; therefore, a change in the external conditions, i.e., the removal of the reward, should produce a relatively small impairment in the maze performance. On the other hand, removing the internal conditions which arouse the drive, i.e., satiation of the animal, should produce a relatively great impairment of the maze performance. Thus, after rats have had only a few trials in the maze under normal conditions of being hungry and rewarded, satiation should produce a much greater increase in errors than removal of reward.

Later in the learning process the drive becomes externalized and the external factors become more important in the arousal of drive

*Received in the Editorial Office on August 16, 1940.

[1]The experimental work here reported was carried out in the psychological laboratories of Professor K. S. Lashley at Harvard University.

[2]I.e., whatever neural mechanism is involved in the production of the persistent behavior that leads to learning.

than they had been in the earlier trials. Disturbance or change in the external factors of the situation (removing the reward) might therefore be expected to produce a greater impairment of performance than would be produced by a similar change early in the learning process; that is, removal of reward late in the learning process should produce a greater increase in errors than the removal of reward early in the learning process. Since the internal factors are of relatively less importance after externalization has taken place, change in the internal conditions of the organism late in the learning process should produce less disturbance than would be produced by a similar change early in learning. That is, satiation (a change in the internal condition of the organism) late in the learning might be expected to produce a smaller increase in the number of errors made than would satiation early in the learning process. Under ideal conditions, satiation should produce a greater disturbance than removal of reward on the early trials of a maze whereas later in the learning, removal of reward might be expected to produce a greater increase in errors than would satiation.

In the earlier paper (2) it was pointed out that this last prediction is subject to error for the following reasons: (*a*) Hunger produces an increase in activity even when no food reward is present (5) and also facilitates learning, in a situation which has never involved a food reward (4). This general facilitating effect of the hunger condition might therefore tend to make the removal of reward group somewhat better than it would be otherwise. (*b*) Since externalization is assumed to involve most of the stimulus situation, removing the reward takes away only one factor in the external situation, leaving many other stimuli facilitating the externalized drive; thus the removal of the reward group may be better than would otherwise be expected. (*c*) The sudden satiation of animals that have been upon a restricted diet for a number of days can be expected to produce a marked change in the physiological condition of the organism and may produce a "satiation shock" effect. The extent of this shock effect might well be greater the longer the animals had been maintained upon a restricted diet, i.e., the shock effect of satiation may be greater late in the learning process than early in learning. Because of these three factors, groups satiated late in the learning process might not show less disturbance than the removal of reward groups. The safest prediction that may

be made would seem to be that the difference between satiated and reward groups should be less late in the learning process than it was early in the learning process. The present paper presents the results of two experiments dealing with the effects of the removal of reward and of satiation upon maze performance at different stages in the learning process.

B. Experiment I

1. *Procedure*

Three groups of 10 pigmented male rats each were used in this experiment. The animals were three to four months old at the beginning of the present experiment. All animals were given the following preliminary training: food was removed and the rats were fed in individual feeding boxes once per day for 11 days. During this preliminary feeding period the time that each rat was allowed to eat per day was so adjusted that each animal gradually lost weight until his body weight was 80 per cent of the original weight before food had been removed. When this point was reached, the daily eating time was adjusted so that each animal's body weight remained approximately constant at the 80 per cent level. After 11 days of preliminary feeding, the animals were given 11 preliminary trials (distributed over seven days) in a straight runway six feet long; food reward was given at the end of the run. During the last eight trials on the runway, black curtains were placed in the runway at various points. After this preliminary training all animals were put on a maze under normal conditions of hunger and food reward. The reward used was a wet mash made by mixing powdered dog food with water.

The maze used was a 14-unit alley T-maze of the Stone pattern, the true path sequence being *RLLRRLRRLRRLLR*. Black cloth curtains were placed five inches from each side of every choice point to prevent the use of vision. An error was counted if the animal entered a blind alley up to the curtain. Manually operated metal doors were placed at each choice point so that no retracing was permitted and only one error for a given blind alley was counted on any one trial. All animals were given one trial per day for 38 days on the maze under the following conditions:

Group C—control group. The 10 animals of this group were

hungry and received a food reward on each of the 38 trials in the maze.

Group RR—removal of reward group. The 10 animals of this group were hungry throughout the maze period of 38 trials. Food reward was present on the first seven trials but was removed for Trials 8 to 12. Since the effect of the removal of the reward would come following the removal, Trials 9 to 13 represent the period during which the effect of the removal of the reward would be obtained. Food reward was again present from Trials 13 to 28 and Trials 29 to 38 give a second period when no reward was given at the end of the maze.

Group S—satiated group. The 10 animals of this group were hungry and rewarded for the first eight trials on the maze; immediately after Trial 8, wet mash was placed in the animal's cage and food was present in the living cage throughout the thirteenth trial. Fresh mash was put in the cage one hour before each of the daily runs during the satiation period to insure complete satiation. A food reward was present at the end of the maze during the satiated trials although the animals rarely ate it. After the thirteenth trial, food was removed from the animal's cage and Trials 14 to 28 represent a period of hunger motivated trials with a food reward. Immediately after Trial 28, food was again placed in the animal's cage and 10 more satiated trials were given, Trials 29 to 38.

One trial per day was given to all groups throughout the learning period. The daily feeding period for all animals running under hunger conditions was placed one hour after the animal's daily trial on the maze. This procedure was used to insure that the rats of the removal of reward group were not motivated by being fed immediately after the maze trial. The three groups were equated on the basis of the errors made on the first seven trials of the maze, that is, before the experimental conditions had been introduced.

2. *Results and Discussion*

a. Error scores. The error scores for the three groups are presented in Table 1. The results are in terms of the average error per rat per trial for the groups of trials indicated. Introducing the experimental conditions early in the learning process (Trials 9-13) results in the satiated group making an average of 6.18 errors

TABLE 1

THE EFFECT OF REMOVAL OF REWARD AND OF SATIATION AT DIFFERENT STAGES OF THE LEARNING PROCESS

Results are in terms of the average error per rat per trial for the groups of trials indicated. Experimental periods are italicized. *C*=control group; *RR*=removal of reward group; *S*=satiation group.

Group	1-3	4-8	*9-13*	14-18	19-23	24-28	*29-33*	*34-38*
				Trials				
C	7.57	5.84	4.44	3.38	1.98	1.54	1.44	1.14
RR	7.50	5.50	*4.88*	2.68	1.90	1.86	*2.08*	*2.78*
S	7.57	5.46	*6.18*	3.26	1.78	1.36	*2.30*	*3.06*

per trial, while the removal of the reward group makes an average error of 4.88 in these trials, and the control group an average error of 4.44. This part of the experiment thus verifies the prediction that satiation is more detrimental than removal of reward early in the learning process. The removal of reward group shows an increase over the control group of only .44 error during this period, while the satiated group shows an increase of 1.74 errors over the control. The satiated group makes 27 per cent more errors than does the removal of reward group.

For the first five trials of the experimental conditions introduced late in the learning period, Trials 29-33, the removal of reward group makes an average error per trial of 2.08, the satiated group an average error of 2.30, and the control group 1.44 errors per trial. The satiated group thus made about 11 per cent more errors than the removal of the reward group. Although the theory of externalization implies that, under ideal conditions, the satiated group should show less disturbance than the removal of the reward group, such a result was not obtained here. It was pointed out in the introduction that three factors tend to handicap the satiated group as compared with the removal of reward group. Because of these complicating factors, it was suggested that a safer prediction would be that the difference between the satiated and removal of reward groups should be less when these conditions are introduced late in learning than when they are introduced early in the learning process. The results confirm this latter implication: early in learning (Trials 9-13) the satiated group made an average of 1.30 or 27 per cent more errors than the removal of reward group, while late in learning the satiated group made an average of .22 or 11

per cent more than the removal of reward group. Thus, on either an absolute or relative basis, the difference between the two groups is less late in learning than it is in the earlier trials. The results are thus in general agreement with the theory but are not entirely satisfactory, especially since the different groups did not remain perfectly equated during the control periods (compare Trials 19 to 28, for example).

The additional five trials of the experimental conditions introduced at Trials 34 to 38 show a still further increase in errors for both the satiated and removal of reward groups over Trials 29 to 33. Since only five experimental trials were given early in the learning process it is not possible to compare the effects of these last five trials with a corresponding period earlier in learning. It is to be noted, however, that the satiated and the removal of reward groups make about the same number of errors in this last series of five trials (3.06 and 2.78).

The theory also suggests that removal of reward should produce a greater disturbance late in the learning process than does removal of reward early in the learning process. This comparison is difficult to make since the number of errors made in the two periods is different. However, the average increase in error over the control group for Trials 9 to 13 was .44; for the later experimental period the increase is .64 errors. This corresponds to an increase for the removal of reward group over the control group of 10 per cent for the early trials and of 44 per cent for the later trials. Both relative and absolute comparisons are thus in agreement with the prediction. A further implication of the theory was that satiation late in the learning process should produce less disturbance than satiation early in learning. The satiated group made 1.74 errors more than the control group early in learning and .86 errors more than the control group late in learning. This result is in agreement with the theory but comparison made on the relative basis gives opposite results; that is, satiation early in the learning process produced an increase in errors of 39 per cent over the control group, while satiation late in learning produced an increase of 60 per cent over the control group.

The results then, in general, are in agreement with the theory of externalization outlined in the introduction to this paper, but are, of course, only suggestive since the groups are too small to yield significant differences.

The disturbance of performance or "disintegration" of the maze habit induced by removing the reward or by satiating the animals does not appear to involve the forgetting of the maze pattern. After the completion of the second experimental period an additional trial (Trial 39) was given to all animals under normal conditions of hunger and reward. Introduction of reward to the removal of reward group after Trial 38 resulted in a drop of the error score to an average of 1.4 on the next trial. Making the satiated animals hungry after the experimental period was followed by a drop in error score to an average of 1.2 on Trial 39. The control group score for the corresponding trial was 1.3 errors. Thus, after 10 trials under conditions of removal of reward or satiation, one trial under normal conditions of motivation and reward is sufficient to bring the experimental groups down to the control group level.

b. Time scores. Since time scores are apt to be influenced by the general activity level of the animal, and since the activity level is markedly affected by the hunger condition regardless of whether or not a reward is present, it might be expected that the deductions from the theory of externalization would not hold for time scores; instead, it might be expected that the removal of reward groups would have lower time scores than the satiated groups at all stages of the learning process. As Table 2 shows, the time scores for the

TABLE 2

TIME SCORES SHOWING THE EFFECT OF THE REMOVAL OF REWARD AND OF SATIATION INTRODUCED AT DIFFERENT STAGES OF LEARNING

The scores are in seconds and are the averages of the median time score per trial for the groups of trials indicated. Experimental periods are italicized.

	Trials							
Group	1-3	4-8	*9-13*	14-18	19-23	24-28	*29-33*	*34-38*
C	159	80	46	37	23	24	23	20
RR	146	73	*106*	41	24	24	*36*	*63*
S	143	79	*172*	41	26	19	*95*	*112*

satiated group are always markedly inferior to those of the removal of reward group. The satiated animals tend to be quite slow in running the maze and are especially slow in starting to run. They are also easily disturbed when in the maze and it is necessary to maintain strict conditions of quiet and absence of movement to avoid distracting them.

C. Experiment II

This experiment was designed to obtain further evidence concerning the effects of satiation and removal of reward with special reference to the rôle of the food box in externalization of drive. If externalization spreads to the food box, then, under certain conditions, a change in the food box might be expected to produce an increase in errors. The following implications of the theory of externalization of drive apply to the later stages of learning, i.e., after there has been an opportunity for externalization to spread to the reward or food box. If a food box is changed for a group of animals that is hungry and receiving a food reward, little effect upon error scores may be expected since an important part of the external situation, namely, the food itself, is still present. With hungry animals, removal of reward from the food box at the end of the maze can be expected to result in an increase in errors since an important aspect of the external situation which might arouse an externalized drive has been altered. And with such hungry nonrewarded animals a further change in the external situation, i.e., a change in the food box, can be expected to result in a still greater increase in error score. Removal of the reward from hungry rats plus the substitution of a new food box at the end of the maze should therefore impair maze performance more than removal of reward without any change in the food box.

Satiation essentially removes the internal physiological conditions which are important in the arousal of the drive mechanism but, of course, does not alter the external situation which arouses the externalized drive. If complete externalization of drive were obtained, that is, if a stage were reached where the internal physiological conditions produced by food deprivation were no longer important in the arousal of the drive, then satiation would not impair performance at all. Such a complete degree of externalization is probably attained rarely, if at all, by the rat; internal conditions remain important determiners of motivation but their relative importance will become less as externalization occurs. The external factors, on the other hand, become increasingly important as experience in the same situation continues and as externalization takes place. Since complete externalization probably does not occur in the rat and internal conditions thus retain some importance, removal of those internal conditions by satiating the animal can be expected to impair per-

formance even very late in the learning process. If, in addition to altering the internal conditions by satiation, changes are also made in those aspects of the external situation which serve to arouse the externalized drive (e.g., by removing the food reward or by changing the reward box) a further impairment of the maze performance may be expected, and this impairment should show some increase with an increase in the number of aspects of the external situation which are altered or removed. Thus, late in learning, satiation plus removal of reward should result in a greater increase in error score than would satiation alone. Likewise, satiation plus the substitution of a new reward box at the end of the maze (without, however, removing the food) should produce more errors than satiation alone. The greatest increase in errors should result from altering or removing several factors simultaneously, that is, by simultaneously satiating the animals, removing the reward, and changing the food box.

1. *Procedure*

A total of 40 pigmented male rats divided into eight comparable groups of five animals each was used in the present experiment. Some of the animals were those used in Experiment I, and additional animals were given the necessary training to give them comparable experience. The rats were five to six months old at the start of this experiment. The same 14-unit T-maze was used for this experiment as was used in Experiment I and the animals were given one trial per day. Before the experimental conditions were introduced, all animals had had 53 trials on the maze. The eight groups used were equated on the basis of the errors made on Trials 46 to 52 and on the basis of the past experience of the animals, that is, whether they had belonged to the satiated, reward, or control groups of Experiment I. All experimental conditions were introduced in such a way that the effect of the given condition would first be shown on Trial 54 of the maze. Eight experimental trials were given, Trials 54 to 61. As in Experiment I, animals of the hungry group did not receive their daily ration until one hour after they had completed their daily run. The following pairs of experimental conditions were studied:

1. *Hunger vs. satiation.* As in Experiment I, animals of the hunger groups were allowed to eat a sufficient time daily to keep

their body weight at 80 per cent of their original base weight; satiation was produced by allowing the animals to eat for one hour daily just preceding their trial on the maze rather than by having food present in the cages at all times as in Experiment I.

2. *Reward vs. no reward.* As in Experiment I, the reward was removed from the food box of the maze for some of the groups but was present for others.

3. *Old food box vs. changed food box.* For some groups the old food box which had been used for the first 53 trials of the maze was continued in use throughout the experimental period; for other groups a new food box was substituted for the old one so that its effect should come on Trials 54 to 61. The old food box was an unpainted box whereas the new box was painted black but of the same dimensions as the old box.

The above conditions were combined in such a way as to form eight different groups as follows:

Group 1-*HRO*; hungry, rewarded, old food box.
Group 2-*HRC*; hungry, rewarded, changed food box.
Group 3-*HNO*; hungry, no reward, old food box.
Group 4-*HNC*; hungry, no reward, changed food box.
Group 5-*SRO*; satiated, rewarded, old food box.
Group 6-*SRC*; satiated, rewarded, changed food box.
Group 7-*SNO*; satiated, no reward, old food box.
Group 8-*SNC*; satiated, no reward, changed food box.

2. *Results and Discussion*

The average errors per trial for the eight trials preceding the experimental period and for the eight trials of the experimental period itself are presented in Table 3. The results will be discussed according to the implications of the theory of externalization of drive presented in the introduction to Experiment II.

a. Removal of reward from hungry animals. With hungry animals, the internal physiological conditions which arouse the drive mechanisms and lead to persistent behavior are present. The theory of externalization implies that such internal conditions become relatively less important as externalization takes place, but in an organism such as the rat, the influence of such internal conditions can never be entirely ignored. Thus with hungry animals, the food reward would remain an important aspect of the external situation to

TABLE 3

THE EFFECT OF SATIATION, REMOVAL OF REWARD, AND CHANGE OF FOOD BOX INTRODUCED LATE IN LEARNING

Results are in terms of the average error per rat per trial for the trials indicated Trials 46 to 53 are a control period during which all groups were hungry, rewarded, and ran to the old food box. The experimental conditions were introduced so as to affect trials 54 to 61.

Group	Condition	Reward	Food box	Trials 46-53	Trials 54-61
1-*HRO*	hungry	yes	old	.38	.55
2-*HRC*	hungry	yes	changed	.43	.33
3-*HNO*	hungry	no	old	30	1.18
4-*HNC*	hungry	no	changed	.35	1.50
5-*SRO*	satiated	yes	old	43	1 45
6-*SRC*	satiated	yes	changed	.35	1.98
7-*SNO*	satiated	no	old	.35	1.65
8-*SNC*	satiated	no	changed	.35	3.20

which externalization takes place. Removal of reward from hungry animals would therefore be expected to impair maze performance.

(1). *Removal of reward without change in food box.* Removal of reward from hungry animals without change in food box produces the expected increase in errors over the hungry animals which are given a reward without change in food box. Group 1-*HRO* (hungry, rewarded, old food box) made an average error of .55 for Trials 54-61, while Group 3-*HNO* (hungry, no reward, old food box) made an average error per trial of 1.18.

(2). *Removal of reward with change in food box.* Removal of reward from hungry animals with change in their food box produces the expected increase in errors over hungry rewarded animals which also had the food box changed. Group 2-*HRC* (hungry, rewarded, changed food box) made an average error of .33, while Group 4-*HNC* (hungry, no reward, changed food box) made an average error of 1.50 per trial for Trials 54-61.

Thus, whether the old food box or a new food box is used, removal of reward from hungry animals results in an increase in error score.

b. Removal of reward from satiated animals. With satiated animals, the original internal conditions which might arouse the drive mechanisms are no longer present. The arousal of motivated behavior is probably, therefore, largely dependent upon the existence

of an external situation to which the drive has become externalized, and any change in that external situation can be expected to produce a greater impairment of performance than would be produced by satiation alone without simultaneous change in the external situation. Hence removal of reward combined with satiation may be expected to produce more errors than satiation with reward present.

(1). *Removal of reward without change in food box.* With satiated animals running to the old food box, the additional condition of removal of reward produces the expected increase in error score. Group 7-*SNO* (satiated, no reward, old food box) made an average error of 1.65, while Group 5-*SRO* (satiated, rewarded, old food box) made an average error of 1.45.

(2). *Removal of reward with change in food box.* With the conditions of satiation and changed food box held constant, the additional condition of removal of reward produces the expected increase in errors. Group 8-*SNC* (satiated, no reward, changed food box) made an average of 3.20 errors per trial, while Group 6-*SRC* (satiated, rewarded, changed food box) made an average of 1.98 errors.

Thus, whether the old food box or a new food box is used, removal of reward combined with satiation produces more errors than does satiation alone.

c. Change of food box with hungry animals. It is assumed that externalization takes place not only to the food reward but also to the reward box and other aspects of the external situation. A change in the food box alters the external situation and should therefore produce some increase in error score.

(1). *Change of food box with reward present.* Change of food box in groups which are hungry and receiving a reward would not be expected to produce much change in error score since a very important aspect of the external situation, the food itself, is still present. Group 2-*HRC* (hungry, rewarded, changed food box) is actually somewhat better than Group 1-*HRO* (hungry, rewarded, old food box) in spite of the change in food box (.33 errors vs. .55 errors). Theoretically, some slight and probably very temporary disturbance might be expected from the change of food box. This expectation is not confirmed by the present experiment. It is possible that with well trained hungry, rewarded animals, externalization

to a new food box occurs very rapidly (within one trial or two). Any effect of the changed food box would therefore be slight and very temporary and could probably be shown only by the use of very large groups of animals. Bruce (3) has reported a slight temporary disturbance in excess distance and time scores produced by a change in the food box of a very simple maze as early as the eleventh trial, even in hungry rewarded animals. This may suggest that, in a simple maze at least, externalization to the food box takes place fairly early in learning and might be sufficiently important to affect, performance even when the food reward is not changed. Essentially, externalization may occur to this-food-in-this-box rather than occurring first to the food and then spreading to the box. If so, change of the food box should produce a disturbance in performance as early in learning as does removal of reward. If the process is serial, there should be a period during which removal or change of reward should disturb performance but during which change of food box without change of reward should not. Following such a period, there should then be a period during which change of either reward or reward box could be shown to affect performance.

(2). *Change of food box with reward removed.* Change of food box for hungry non-rewarded animals would be expected to result in an increase in errors over those of hungry non-rewarded animals which retain the old food box. Group 4-*HNC* (hungry, no reward, changed food box) made an average error of 1.50 during the experimental period, while Group 3-*HNO* (hungry, no reward, old food box) made an average error of 1.18.

Change in the food box, therefore, seems to produce an increase in error score with non-rewarded animals.

d. Change of food box with satiated animals. For the reasons discussed above under the removal of reward from satiated animals, any change in the external situation combined with satiation should produce more errors than satiation alone. Hence a change of food box combined with satiation should produce a greater increase in error score than satiation alone.

(1). *Change of food box with reward present.* With satiated animals receiving a food reward, a change of the food box produces a further increase in errors. Group 6-*SRC* (satiated, rewarded, changed food box) made an average of 1.98 errors per trial, while

Group 5-*SRO* (satiated, rewarded, old food box) made an average of 1.45 errors. Thus, with animals dependent upon the external situation for the arousal of motivation, a change in one part of the external situation (the food box) produces more errors than does satiation alone without a change in the external situation.

(2). *Change of food box with reward removed.* With the conditions of satiation and removal of reward held constant, change of food box results in a greater increase in errors than if no such change is made. Group 8-*SNC* (satiated, no reward, changed food box) made an average error per trial of 3.20, while Group 7-*SNO* (satiated, no reward, changed food box) made an average error of 1.65. As is to be expected, the most marked disturbance in error score results from eliminating internal sources of arousal of drive through satiation and by making a relatively complete change in the external situation by removing the reward and changing the food box. Group 8-*SNC*, tested under these conditions, has a higher error score than any other group.

e. Satiation versus change in the external situation. At this late stage in the learning process, a relatively complete change of the external situation without alteration of the internal hunger condition of the animal is as detrimental to performance as is alteration of the internal condition of the organism without change in the external situation. Group 4-*HNC* (hungry, no reward, changed food box) made an average of 1.50 errors per trial, as compared with an average of 1.45 errors per trial made by Group 5-*SRO* (satiated, rewarded, old food box). In Experiment I it was shown that satiation *early* in learning is more detrimental than removal of reward.

f. Removal of reward versus change in food box. On the basis of practically any theory, or of no theory at all, it might be expected that removal of reward from hungry animals would produce a greater increase in errors than merely changing the food box without removing the reward. The results clearly show that such is the case. With satiated animals, however, the opposite effect is obtained; that is, change in the food box appears to produce a greater increase in error score than does removal of reward. For the satiated rewarded animals (Groups 5 and 6) a change in the food box results in an increase of .53 in error scores, while for the satiated non-rewarded animals (Groups 7 and 8) a change in the food box

produces an increase of 1.55 in error score. Combining both groups, a change in food box produces an average increase in error score of 1.04 for the satiated animals. For the satiated animals running to the old food box (Groups 5 and 7) removal of reward results in an increase of .20 in error score, while for the satiated animals with a changed food box (Groups 6 and 8) removal of reward results in an average increase of 1.22 errors. Again combining groups, removal of reward produces an average increase of .71 errors for the satiated animals. Thus, for the satiated animals, the food box seems to have become more important than the food itself, and a change in the food box produces more errors than removal of reward. The writer has not yet been able to relate this finding to the theory of externalization of drive.

g. Response of the satiated animals to the food reward. The theory of externalization of drive would lead to the expectation that some of the satiated animals should occasionally eat the reward in the food box. That is, if the drive has become externalized to the food, the mere presentation of the external situation, the food, should lead to eating. Records of the behavior of the satiated animals in the reward box were kept for 10 rats for 7 trials each. In the 70 observations, 32 instances of eating were noted. Often the eating response was perfunctory, the animal would take a small nibble and then turn away from the food. In other cases the rat would eat steadily for several seconds. The reactions of the satiated animals to the food are thus in agreement with the theory of externalization of drive, but such behavior might also be expected if the animals were not completely satiated at the time of the maze performance. Thus it might be argued that the good performance of some of the satiated animals was due to the fact that they were not actually satiated. Such an argument would necessarily imply that fewer errors should be made upon the trials at which eating of the reward occurred than upon those trials on which the reward was not eaten. The facts are directly opposed to such an interpretation: The average error for the 32 instances of eating by the satiated animals was 1.56, and for the 38 instances in which the reward was not eaten, the average error was 1.58. The good trials of the satiated animals cannot therefore be attributed to any assumed lack of satiation, since eating the reward appears to be unrelated to goodness of performance.

h. "Satiation shock" effect. Part of the disturbance of the satiated groups may be due to the satiation shock effect previously mentioned. Since the animals had been on a reduced diet for several weeks, the sudden presentation of all the food they could eat seemed to produce a rather stuporous condition in the animal. On the other hand the effect of removal of reward seems to be delayed for a trial or two, presumably while the animals are learning that no reward is present at the end of the maze. This effect is shown in Table 4 which presents the average error per trial for

TABLE 4

THE EFFECT OF REMOVAL OF REWARD, SATIATION, AND CHANGE OF FOOD BOX SHOWN BY THE AVERAGE ERROR PER TRIAL FOR EACH TRIAL OF THE EXPERIMENTAL PERIOD; ALSO, THE NUMBER OF PERFECT RUNS MADE BY EACH OF THE FIVE RATS IN THE DIFFERENT EXPERIMENTAL GROUPS

Group	54	55	56	Trial 57	58	59	60	61	Perfect runs
1-*HRO*	.6	1.2	.2	4	.2	.0	.8	1.0	1, 6, 8, 8, 8
2-*HRC*	.8	.8	.4	.2	.0	.4	.0	.0	4, 7, 7, 7, 8
3-*HNO*	.4	.4	1.2	1.0	1.2	2.4	1.2	1.6	1, 2, 3, 6, 7
4-*HNC*	.4	.4	1.0	1.8	2.4	1.8	2.8	1.4	0, 3, 4, 6, 8
5-*SRO*	2.6	1.6	.8	.8	.6	1.6	2.0	1.6	1, 1, 1, 6, 7
6-*SRC*	1.2	2.0	1.6	1.6	1.8	2.2	1.8	3.6	0, 0, 0, 3, 4
7-*SNO*	1.8	1.4	1.8	1.8	2 0	1.4	1.6	1.4	0, 0, 4, 6, 8
8-*SNC*	2.6	2.4	1.8	5.2	2.8	2.6	4.2	4.0	0, 0, 1, 1, 1

each of the groups on each trial of the experimental session. The hungry groups with removal of reward show practically no disturbance on the first two trials, while the satiated group which had no changes made in the external situation (Group 5) shows the most marked disturbance on the first trial after satiation. The performance then becomes markedly better for a few trials. The possible existence of the satiation shock effect would appear to handicap the satiated groups in any comparison with non-satiated animals.

i. Individual performances of some of the satiated and removal of reward animals. Some of the animals of the satiated and no reward groups made very excellent performances during the experimental period, in two cases even completing the eight trials without making a single error. The last column of Table 4 shows the number of perfect runs made by the animals during the experi-

mental period of eight trials. The numbers in this column are read as follows: of the five rats in Group 1, one made one perfect run, one made six perfect runs, and three rats made eight perfect runs each. It is clear from the table that some of the animals continue to make many perfect runs under conditions of removal of reward or/and satiation. The fact that even a few rats continue to run the maze perfectly under such conditions is entirely in agreement with the theory of externalization of drive. It has been suggested elsewhere (2) that externalized drives are essentially a specific case of autonomous motives, and the continuation of the maze habit after the motivational conditions have been markedly diminished is also clearly in agreement with Allport's theory of the functional autonomy of motives (1).

It is recognized that results based upon groups as small as those used in the present experiment cannot be conclusive. The consistency of the obtained results with the theory, however is certainly suggestive, and in experiments dealing with the effects of satiation or removal of reward, the stage of learning at which the experimental conditions are introduced is a factor which should be considered.

D. Summary

The implications of the theory of externalization of drive are considered with reference to the effects of satiation and removal of reward at different stages of the learning process, and with respect to the effects of a change in food box. The following implications of the theory were tentatively verified, although the groups used were too small to yield statistically conclusive results.

1. Satiation early in the learning process produces a greater increase in error score than does removal of reward at the same stage in learning.

2. At later stages of learning, after externalization of drive has taken place, removal of reward or satiation produce about the same disturbance in error score.

3. Removal of reward appears to be more detrimental when introduced late in the learning than when introduced early.

4. The theory leads to the expectation that satiation should produce a less detrimental effect when introduced late in learning than when introduced early. This finding is verified for the absolute

error difference but not for the relative error difference. It is suggested that a "satiation shock" effect may be a complicating factor.

5. Late in the learning process, a change of the food box at the end of the maze introduced together with removal of reward or satiation results in a further increase in error score.

6. Removal of reward from satiated animals produces more errors than does satiation without removal of reward.

7. The most pronounced disturbance in error score is produced by simultaneously changing both the internal condition of the animal and the external situation, that is, by satiating the animals, removing the reward, and changing the food box.

8. Time scores do not seem to follow the same principles as the error scores. Satiated animals always make poorer time scores than do the removal of reward groups. It is suggested that this result may be due to the facilitating effect of the hunger condition upon general activity.

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Department of Psychology
Wilson College
Chambersburg, Pennsylvania

The Journal of Genetic Psychology, 1941, 59, 377-387.

THE DEVELOPMENT OF THE ABILITY TO DISCRIMINATE AND MATCH NUMBERS*

College of City of New York; and Institute for Research in Child Psychology, Hunter College

LOUIS LONG AND LIVINGSTON WELCH

A. INTRODUCTION

The relationship between the ability to learn hierarchical concepts and the ability to discriminate and match numbers was investigated in a previous experiment (3). No attempt was made at that time, however, to study the interrelationship between the number tests. Such an analysis will be undertaken in the present paper. The three number tests of the study referred to above were given to 135 children ranging in age from 30 months to 83 months. The three tests will be referred to as number discrimination, number matching, and group matching.

In this analysis the aim will be to study the effect of chronological age and mental age on the ability to discriminate and match numbers, as measured by the three number tests. The number tests will be treated both as individual tests and as a battery of tests measuring one general ability which can be referred to as "quantitative perceptual ability." The discussion will center around the following points: (*a*) the internal consistency of the three tests when combined into a single test of quantitative perceptual ability; (*b*) the importance of *CA* and *MA* in accounting for the presence of this ability; and (*c*) the contribution of *CA* and *MA* to the performance in any one of the three tests.

B. PROCEDURE AND MATERIALS[1]

The discrimination materials in all three situations were marbles. In the *number discrimination test* one group of 10 marbles and a second group of from one to 10 marbles were displayed to the

*Received in the Editorial Office on August 15, 1940. This study was done while one of the authors (L. L.) was a member of the staff of the Normal Child Development Study of the Department of Pediatrics, Columbia University and the Babies Hospital. This work has been aided by a grant from the Social Science Research Council.

[1]This procedure is identical with that reported in a previous publication (3).

child in the inverted lids of two boxes. The lids, which served as trays for the marbles, were glued to the bottoms of the boxes so that a reward might be placed under the box displaying the positive stimulus. The marbles were not attached to the lids in order that no clue should be obtainable from the pattern they might form. After each trial the position of the positive box was irregularly shifted from the left to the right, and from the front to the back of the negative box, so that the child could not profit by cues of position sequence. The child was told that he would always find a toy under the box with the most marbles. He was given 10 preliminary trials in which the positive box contained 10 marbles and the negative box but one marble.

When the test trials began 10 marbles were placed in the positive box and five in the negative box. The child was again instructed to choose the box with the greater number of marbles. The criterion was nine successful trials out of 10. If the child failed to satisfy the criterion, one marble was removed from the negative box and 10 more trials were given. If he failed again, an additional marble was removed. This procedure was continued until the criterion was fulfilled. If the child satisfied the criterion of nine correct trials out of 10 when five marbles were paired with 10, a marble was added to the negative box and 10 more trials were given. This procedure was continued until more than one error was made in 10 trials or until the number of marbles in the negative box equalled that in the positive. The score was the largest number of marbles correctly discriminated from 10 marbles; thus a score of six indicates that the child satisfied the discrimination criterion when 10 marbles were paired with six marbles, but failed with seven marbles.

In the *number matching test*[2] two marbles were placed in front of the child. He was handed 10 to 15 marbles and told to make a pile himself, alongside of the original, that was "just as big." If he succeeded, these marbles were replaced by a new pile of three marbles. This procedure was continued until he failed to match the pile of marbles. The score assigned to the child was the largest group of marbles that he matched correctly. Thus a score of six indicates that the child succeeded in matching a group of six marbles, but failed when seven marbles were to be matched.

[2]These tests were referred to as Matching *A* and *B* respectively in the previous paper (3).

In the *group matching test*[2] four distinct groups of marbles were placed within a radius of six inches of each other. Two of the groups contained two marbles each; the other two groups contained three marbles each. The subject was instructed to point out the groups containing the most marbles; then he was asked to select the piles with the smallest number of marbles. If he succeeded, all these marbles were removed, and two groups of three and two groups of four marbles were placed in the same radius, though in different positions. In this manner the number of marbles in the piles was increased until a point was reached at which the child failed to discriminate the larger groups from the smaller. The number of marbles in the largest group correctly discriminated was assigned to the child as his score on this test. Thus a score of three indicates that the two groups of two marbles and the two groups of three marbles were recognized as the smallest and largest piles of marbles respectively, while the child failed when two groups of three and two groups of four marbles were presented.[3]

D. Subjects[4]

There were 135 subjects ranging in age from 30 to 83 months. They were obtained from the institutions listed in Table 1.

TABLE 1

Institutions	Age range in months	Boys	Girls	Total
Normal Child Development Study of Columbia University	32-78	12	5	17
Manhattanville Day Nursery (N.Y.C.)	30-69	20	9	29
Hunter Model School (N.Y.C.)	60-83	21	24	45
Bethany Day Nursery (N.Y.C.)	30-70	23	13	36
Washington Heights Day Nursery (N.Y.C.)	37-60	4	4	8
Total		80	55	135

[3]An attempt was made to discourage counting whenever it was observed.

[4]We wish to express our gratitude to Miss M. B. Pierce of the Manhattanville Day Nursery, to Miss E. Clash of the Bethany Day Nursery, to Miss K. Burton of the Washington Heights Day Nursery, and to Professor E. Keith of the Hunter Model School, for their courtesy and co-operation in allowing us to give these tests.

We are also indebted to the following for their assistance: Mrs. M. Lukomnik, Miss K. Farmer, Miss M. Smith, Miss V. Friedson, Miss R. Isacson, Miss D. Dubinsky, Miss R. Leder, Miss B. Gioscia, Miss C. Blume, and Miss R. Imberman.

E. Socio-Economic Status

The socio-economic status of most of the children is about average for New York City families. That for the Hunter Model School children is perhaps a little higher.

F. Intelligence Ratings

The intelligence ratings were taken from the files of the institutions mentioned. The children of the Normal Child Development Study and the Manhattanville Day Nursery were given the revised *Stanford-Binet*, and the Hunter Model School children were rated on the basis of the Pintner-Cunningham *Group Test*. No records of intelligence tests were available for the children from the other institutions.

G. Discussion of Results

The average chronological age and the average IQ[5] for the various age groups will be found in Table 2. This table also includes

TABLE 2
Average Scores on Three Number Tests for Various Age Groups

Age groups (months)	No. of S's	Months	Av. IQ	Number discrim.	Number matching	Group matching	Ave. of 3 tests
30-35	15	31.67	—	0.80	0.60	0.40	0.53
36-41	15	37.67	—	1.33	1.47	0.47	1.09
42-47	15	44.27	108	5.20	3.07	1.93	3.40
48-53	15	50.40	104	5.60	3.47	2.60	3.89
54-59	15	55.87	107	6.53	4.27	3.87	4.89
60-65	15	63.13	117	7.60	6 13	4.47	6.07
66-71	15	68.27	113	7.40	7.00	5.40	6.60
72-77	15	73.07	120	7.73	7.40	6.07	7.07
78-83	15	80.40	113	7.87	6.87	6.07	6.93
Total	135						
Av.		56.08	113.48	5.56	4.47	3.47	4.50
SD		15.66	14.68	3.03	2.85	2 90	2.64

a summary of the average scores obtained in the three tests. The scores of the individual tests, as well as of the average of the three tests, indicate that performance varies in a very regular and system-

[5]The average IQ's are based on 67 of the 135 subjects. No records of any intelligence tests were available for the remaining children.

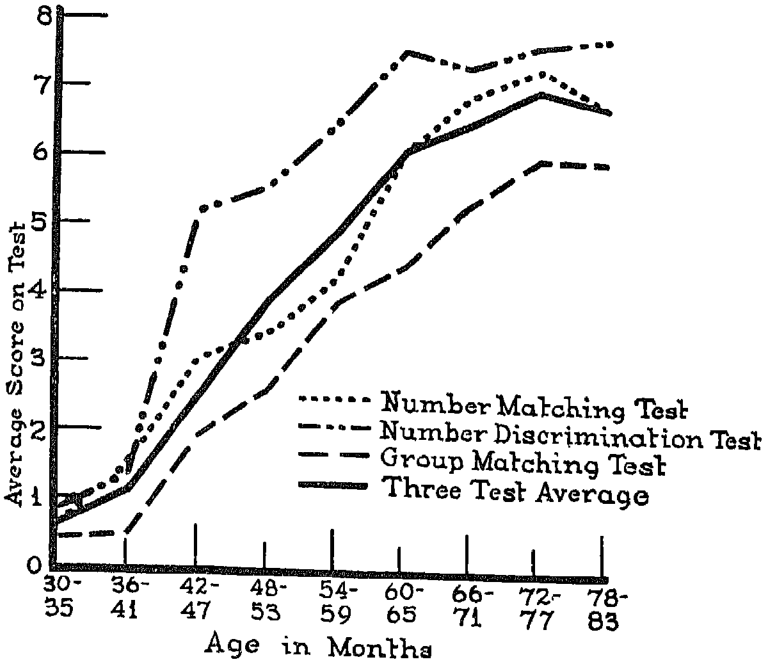

FIGURE 1

Average Scores on Three Number Tests for Various Age Groups

atic manner with age (see Figure 1). All of the average scores improve as age increases. The curves of Figure 1 also indicate that most of the improvement in these tasks occurs within the age range of the subjects of this experiment. That is, the youngest children find the tasks too difficult, while the flattening of the curve at the upper age limit suggests that the major development has occurred by the age of six or seven. Additional evidence on this point can be obtained from a matching experiment performed by Baldwin and Stecher (1). (Their data are presented in Table 3 along with a regrouping of the data of Table 2.) They, too, find a slowing up of the rate of improvement at about this age.

Since these tests can be roughly described as perceptual tests the scores were in one case combined into an average score. In considering the feasibility of such an approach it seemed desirable to

TABLE 3
NUMBER MATCHING TEST
Comparison of Baldwin and Stecher's Data with Data from Present Experiment

Baldwin and Stecher			Long and Welch		
No. of S's	Age in years	Score	No. of S's	Age in years	Score
2	2	1.0			
26	3	2.4	15	3	1.04
27	4	4.7	15	4	3.27
20	5	6.3	15	5	5.20
18	6	7.5	15	6	7.20

determine the variation introduced by each test. Consequently the total variance was calculated by using the deviations of each child from his own mean score. It was found that two tests, number discrimination and group matching, contributed about equally to the total variance, while the number matching test accounted for only about 20 per cent of the total. The scores on the less reliable tests were then averaged, and this average was compared with the average of the scores on the third test. Since it was desirable to make this comparison independent of variation in age, the scores for each child on both tests were predicted from chronological age by means of the regression equations obtained by correlating the scores on the number tests with age. The residuals between the predicted and obtained scores for each child on the two tests were found to be positively correlated (0.40). Thus the tests are to some extent measuring a common factor, but the correlation is too low to assume that the tests are measuring a single trait. One other factor, human variability, should, however, be mentioned as entering in to cause a correlation of less than one. If the tests were repeated on the same children, and the two sets of scores of any one test correlated, we can be certain that a correlation of one would not be obtained. Thus the obtained correlation is lowered to some extent by the impossibility of obtaining perfectly consistent results from the children, but the assumption that the tests are measuring several traits rather than a single trait is still indicated.

Since a measure of the internal consistency of the tests had been obtained, it seemed desirable to determine the relationship between general intelligence and quantitative perceptual ability, in spite of the above finding that the tests probably do not furnish measures of

a unitary trait. Before this could be done it was essential that the obtained scores be corrected for age variation. The average score was correlated with chronological age; from the regression equation of this correlation it was possible to predict the scores the children would receive if they were all of the same age. By subtracting the obtained from the predicted scores residuals were obtained which allow the performances of children to be compared directly.

With scores equated for age it is now possible to study the association between general quantitative perceptual ability and general intelligence, as determined by standard intelligence tests. One method of determining the relationship is to compare the number of subjects scoring above and below the medians on the two variables (i.e., the score residual and the *IQ*). The absence of any striking association between the two abilities is indicated by the uniform distribution of subjects throughout Table 4. (The actual correlation was found to be —0.09.) It will be noted that of the 34 subjects who scored above the median residual score 16 have *IQ*'s less than the median *IQ* and 18 have *IQ*'s above the median. Obviously if the two traits are associated to any appreciable extent we should find fewer of these 34 subjects falling below, and more falling above the median *IQ* score. Such a distribution would indicate that children who scored high in the perceptual tests would likewise have high *IQ*'s. This relationship is, however, not found.

TABLE 4

Number of Subjects Above and Below Median *IQ* and Residual Score *IQ*

	No. of *S*'s		
Residual score	Below median	Above median	Total
No. of *S*'s below median	18	15	33
No. of *S*'s above median	16	18	34
Total	34	33	67

There are several possible explanations of the lack of a reliable correlation between quantitative perceptual ability and general intelligence. It is hardly necessary to mention that the tests are similar in so far as the tests in all cases involve the perception of numbers of marbles, but in other respects the three tests are quite different. For example, in the number discrimination test the task is to select the larger group of marbles; the problem resolves itself to choosing

between two groups of objects—two Gestalts. In the number matching test, a very different perceptual problem is involved. The task is to select the proper number of marbles needed to make the second group equal in number to the first. Thus one group is presented—the other part of the Gestalt has to be supplied. The verbal demands of the group matching test are much greater than in either of the other two tests. The child must understand the meaning of the following concepts: least, most, and alikeness. (In the number matching test it was necessary for the child to understand the concept of sameness or identity, while in the number discrimination only the concept of larger was necessary.) The group matching required a double process: selecting the two piles with the least number of marbles, as well as the two piles with the most marbles. That important differences exist between the number tests is almost as obvious as that there are differences between the various items on the usual test of general intelligence. The absence of a correlation between the average of the perceptual test scores and *IQ* can conceivably be attributed to the heterogeneity of the sub-tests of each measure. There are undoubtedly many other possible hypotheses; however, the only statement that can be made at this time is that we failed to find any significant correlation between the two measures.

In addition to the above analysis the relationship between the individual tests was investigated. To this end each test was correlated with every other test. These correlation coefficients are presented in Table 5, along with various partial correlations. Attention should be called to the three distinct groups of coefficients found in this table. Those of the first group are based on all of the children of the experiment.

The second group was worked out as a result of the observation that many of the children of the three youngest groups did not obtain scores in the tests. Consequently the three youngest groups were excluded from the correlations of the second group (labelled "Older Groups," $N=90$).

The third group of correlations is based upon the 67 children for whom *IQ*'s were available. In this group it is possible to control, or rule out, the effect of *CA* and *MA*, separately or jointly.

This analysis can be considered as a supplement to the foregoing discussion since there is complete agreement on the following points:

TABLE 5
INTERCORRELATONS BETWEEN NUMBER TESTS

	Raw correlations		Partial correlations		
Entire group ($N = 135$) Age range: 30-83 mo.					
	Group Match.	No. Match.	Group Match.	No. Match.	
Number discrimination	0.71	0.71	0.33	0.22	
Number matching	0.73		0.27		*CA* Constant
Older groups ($N = 90$) Age range: 48-83 mo.					
	Group Match.	No. Match.	Group Match.	No. Match.	
Number discrimination	0.46	0.50	0 30	0.32	
Number matching	0.56		0.38		*CA* Constant
IQ group ($N = 67$) Age range: 42-83 mo.					
	Group Match.	No. Match.	Group Match.	No. Match.	
Number discrimination	0.50	0.49	0.31	0.22	
Number matching	0.61		0.42		*CA* Constant
			Group Match.	No. Match.	
Number discrimination			0.37	0.29	
Number matching			0.42		*MA* Constant
			Group Match.	No. Match.	
Number discrimination			0.32	0.24	
Number matching			0.39		*CA* and *MA* Constant

(*a*) a higher correlation between performance on the three tests and chronological age than between performance and mental age; and (*b*) a moderate amount of correlation between the performance on the separate tests when both age variables are partialed out.

In an attempt to study further this problem of relationship between different perceptual tests the performance on the number discrimination test was compared with a different type of number discrimination. The latter experiment involved the discrimination of figures with varying numbers of sides. The procedure used by

Long has been described elsewhere (2). It is sufficient to say that the usual animal type of non-verbal discrimination set-up was employed in establishing a motor response to roundness. After systematic variation of the types of stimuli the child was presented with two-dimensional figures of a constant size but varying in shape. The number of sides of the figures varied from four to 15. These 12 figures and a circle were interpaired so that each stimulus was paired once with every other stimulus. Response to the figure with the larger number of sides (or the circle) caused a pellet of candy to be automatically delivered to the child. Candy was withheld after a response to the negative stimulus. The score is the absolute number of responses to the positive stimuli.

The problem above involves a number discrimination insofar as a response to the figure with the larger number of sides is always the rewarded stimulus. The discrimination of the present experiment was established verbally by instructing the child to select the box containing the greater number of marbles. Now a check on the two procedures and the extent to which the two experiments are measuring number discrimination in general can be obtained by correlating the results obtained by the different techniques. Both tests were administered to 15 subjects. The measure of performance on the number-of-sides problem was the number of responses to the positive stimulus, while the score on the marble test was the same as that used throughout this paper. A correlation of +0.52 was obtained between these two tests, when the effect of variation in chronological age was removed.

The interpretation suggested by the correlation is that the two situations are measuring much the same thing—general number discriminative ability. Agreement is obtained in spite of the fact that in one case the discrimination is between number of marbles and in the other case, between number of sides possessed by different figures.

H. Summary and Conclusions

This is the report of an experiment which made a study of the development of the ability to discriminate and match numbers,—135 children serving as subjects.

Each child was presented with three tasks: (*a*) discrimination of 10 marbles from a varying number of marbles; (*b*) matching a

group of marbles varying in number from two to 10; (*c*) selecting the larger and smaller groups of marbles, when four groups of marbles were presented. In this last situation, the number of marbles varied from two groups of two and two groups of three marbles to two groups of nine and two groups of 10 marbles.

The results indicate that the performance on all three tests improves in a very regular manner as age increases. The suggestion is made that most of the development of the ability measured by these number tests has occurred by the sixth or seventh year.

An analysis of the results suggests that the three tests are not measuring a single trait, but a certain amount of communality is indicated by the correlation of 0.40.

An effort was made to determine the importance of general intellectual ability in the performance on the number tests. A very low and unreliable correlation was obtained. The absence of a correlation between the average of the perceptual test scores and *IQ* is tentatively attributed to the heterogeneity of the sub-tests of each measure. In addition the relationship between the individual tests was investigated, with *CA* and *MA* partialed out. In general this analysis leads to the same conclusions indicated above.

A comparison of two different experimental techniques for studying number discrimination is made on a restricted group of subjects.

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Personnel Bureau
College of City of New York
Amsterdam and 138th Street
New York City

Institute for Research in
Child Psychology
Hunter College
Park Avenue and 68th Street
New York City

The Journal of Genetic Psychology, 1941, **59**, 389-396.

STUDIES ON THE REPRODUCTIVE ACTIVITIES OF THE GUINEA PIG: V. SPECIFICITY OF SEXUAL DRIVE IN THE MALE*[1]

Department of Psychology, Connecticut College

GEORGENE H. SEWARD

A. INTRODUCTION

In a recent investigation of sexual drive in the guinea pig (8), males after deprivation showed a stronger drive to reach a female than after successful copulation. No corresponding drive was found in the female. With respect to the male, the question still remained as to whether the drive discovered was specifically sex-directed, or whether it represented merely a heightening of general activity. The present study was designed to throw light on this question.

A number of studies (2, 3, 13) on the albino rat have correlated general activity with sexual behavior measured either by direct copulatory tests or by an obstruction box. The correlations reported range from +.08 to +.42. Their sign indicates some relationship but their size suggests that factors other than general activity are responsible for intensity of sexual aggressiveness. Some direct evidence for specificity of sexual drive in this species has been presented by Warner (15). A reliable difference in number of crossings in the Columbia obstruction box distinguished deprived males running to a female incentive from those running to an empty compartment. Even satiated males crossed no less frequently to a female than the deprived males to an empty compartment. According to the author these findings indicate the superiority of external incentive to internal condition in the sexual motivation of the male rat. In contrast to the male, the female was apparently dominated by her physiological state, showing significant differences

*Received in the Editorial Office on August 24, 1940

[1]Aided by a grant from the National Research Council Committee for Research on Sex Problems, through the Dept. of Anatomy, Cornell Univ Med. College The writer is personally indebted to Dr. G. N Papanicolaou of that department for his valuable cooperation.

between "cornified" and dioestrous conditions. Not only did cornified females cross more often to the male than to the empty compartment, but their crossings to the empty compartment exceeded those of dioestrous females to males. Since, however, the dioestrous female may be inhibited by the presence of the male due to increased timidity at this time (1), a further comparison between cornified and dioestrous females run to an empty compartment is indicated. If this should yield no significant difference it would weaken the case for dominance of internal as compared with external motivation in the female.

In our work on the guinea pig, the female showed no measurable drive to the male regardless of internal condition. The analysis of specificity, therefore, is necessarily confined to the male. We compared female and empty compartment incentives after satiation as well as deprivation. We also included comparisons between the two internal conditions using an empty compartment incentive as well as a female.

B. Method

1. *Animals*

We selected from the group of animals used in the previous study four males with especially strong sex drive.

Since practical difficulties precluded the use of oestrous females as incentives, we selected normal animals with ruptured vaginas, representing either a pre- or post-oestrous condition. Although the absolute strength of drive might have been greater with receptive females, it is unlikely that this would have altered the relations reported below.

2. *Test Conditions*

By "satiation" we refer to the condition of the male after one ejaculation. This was accomplished under the experimenter's observation in a special cage. The test animal was allowed to copulate freely with a normal female in heat until a vaginal plug was deposited.[2] Following the ejaculation the male remained with the female for five minutes, after which he was given a "satiated" run. Although the temporal course of recovery of copulatory activity was

[2]The time required for satiation varied from animal to animal but in all cases the onset was sudden and marked by an abrupt change in behavior.

not determined, it is apparently slower than that reported by Stone (10) for the rat and never occurred within the experimental period.

A "deprived" run followed a satiation period after an interval ranging from four to ten days. Unfortunately, optima have not been determined for this species, but data on the rat (15) revealed no reliable difference in obstruction box performance between the peak at 24 hours and an interval of seven days. Moreover, there was very little change during the remainder of the 28-day experimental period. Immediately before each deprived run the test animal was permitted five minutes in the observation cage to correspond with the post-satiation period.

3. *Apparatus and Procedure*

In the present study the new hurdle box was used following the standard procedure (9, p. 4-6). The barrier height was seven inches. Each test animal was run under all conditions, but the order of trials was rotated among them to equate for practice and other variables. To insure reliability two complete series of trials were made for each animal. A 15-minute trial in the first series was reduced to 10 minutes in the second. Between trials all males were kept in isolation. Before experimenting was begun the test animals were thoroughly adapted to the experimental cages by systematic daily practice.

4. *Scoring*

Two measures of drive were used: the number of crossings and the average time of crossing. In order to make the second score independent of the first, the average time was based on an equal number of crossings in any two conditions compared, *n* being determined by the smaller total.[3]

C. Results

Table 1 shows the results on the drive to the female incentive under deprived and satiated conditions. In the first two columns appear the average crossing times in seconds. These data show a difference in favor of greater speed on the part of the deprived males. Only two cases fail to bear out this trend. The average of

[3]This method of calculation accounts for the discrepancies in time scores appearing in the different tables under the same column headings.

TABLE 1
FEMALE INCENTIVE

Animal	Average crossing time in seconds Deprived	Satiated	*Diff. S-D*	Number of crossings* Deprived	Satiated	*Diff. D-S*
*SA*7-1	2.57	8.59	6.02	22	23	— 1
2	3 18	14.91	11.73	19	11	8
*SA*5-1	2.09	2.00	— 0.09	28	17	11
2	6.46	19.20	12.72	21	14	7
*SA*9-1	4.00	17.23	13.23	25	13	12
2	3.33	30.39	27.06	20	9	11
*SA*17-1	2.92	37.69	34.77	23	13	10
2	8.96	8.23	— 0 73	18	13	5
Average	4 19	17.27	13.09	14.1	22 0	7.9
σAv. Diff.			4.40			1.52
Crit. Ratio (t)			2.98			5.20

*Each animal's first pair of tests shows the number of crossings in 15 minutes; the second pair, in 10 minutes.

the differences has a critical ratio of 2.98 which is reasonably reliable. The same tendency is brought out even more strikingly in the number of crossings. These results confirm our previous finding cited above that the male guinea pig will cross a barrier more often and more rapidly to a female when sexually deprived than when satiated.

The question whether this difference is specifically sex-motivated rather than due to some correlate of general activity is answered in Table 2, which presents a comparison between the female and empty

TABLE 2
DEPRIVED CONDITION

Animal	Average crossing time in seconds Female	Empty	*Diff. E-F*	Number of crossings Female	Empty	*Diff. F-E*
*SA*7-1	2.83	13.50	10.67	22	6	16
2	6.28	10.88	4.60	19	16	3
*SA*5-1	1.69	66.19	64.50	28	8	20
2	4.35	7.14	2.79	21	7	14
*SA*9-1	4.16	47.50	43.34	25	14	11
2	3.29	36.50	33.21	20	12	8
*SA*17-1	2 20	68.60	66.40	23	5	18
2	8.96	24.07	15.11	18	13	5
Average	4.22	34.30	30.08	22.0	10.1	11.9
σAv. Diff.			9.15			2.18
Crit. Ratio (t)			3.29			5.46

compartment as incentives to deprived males. Again the differences are large and statistically reliable, indicating that the lure of the female is definitely stronger than that of the empty compartment. There is perfect consistency in these data.

Further evidence in the same direction is afforded by Table 3,

TABLE 3
SATIATED CONDITION

Animal	Average crossing time in seconds Female	Empty	*Diff. E-F*	Number of crossings Female	Empty	*Diff. F-E*
*SA*7-1	4.11	22.08	17.97	23	13	10
2	14.91	17.45	2.54	11	14	— 3
*SA*5-1	2.00	4.63	2.63	17	16	1
2	3.00	46.44	43.44	14	8	6
*SA*9-1	7.19	29.25	22.06	13	8	5
2	2.88	4.25	1.37	9	4	5
*SA*17-1	31.50	66.75	35.25	13	4	9
2	5.00	10.00	5.00	13	1	12
Average	8.82	25.10	16 28	14.1	8.5	5.6
σAv. Diff.			5.76			1.73
Crit. Ratio (t)			2 83			3 24

which compares the female and empty compartment incentives in the case of *satiated* males. Again we find clear and consistent trends in favor of the female, in spite of the relatively unfavorable internal condition.

Finally, the importance of the external incentive is indirectly revealed in a comparison of males in deprived and satiated conditions

TABLE 4
EMPTY COMPARTMENT INCENTIVE

Animal	Average crossing time in seconds Deprived	Satiated	*Diff. S-D*	Number of crossings Deprived	Satiated	*Diff. D-S*
*SA*7-1	13.50	11.17	— 2.33	6	13	— 7
2	11.79	27.50	15.71	16	14	2
*SA*5-1	66.19	4.63	—61 56	8	16	— 8
2	7.14	7.00	— 0.14	7	8	— 1
*SA*9-1	3 06	29.25	26 19	14	8	6
2	2.00	4.25	2.25	12	4	8
*SA*17-1	17.38	66.75	49.37	5	4	1
2	10.00	10.00	0	13	1	12
Average	16.38	20 07	3.69	10 1	8.5	1.6
σAv. Diff.			11.23			2.47
Crit. Ratio (t)			0.33			0.65

when running to an empty compartment. These data, presented in Table 4, show no consistent trends and the average differences obtained are not reliable.

D. Discussion

The results of the present investigation have demonstrated the necessity of an external incentive in the sexual motivation of the male guinea pig. The internal condition may be conceived of as a kind of "potential" for response to an external stimulus; the favorable condition of deprivation representing a "higher" potential than the less favorable condition of satiation. But internal condition *per se* is not adequate to bring about a differential response. The external condition is necessary to release the drive. Such findings favor an interpretation in terms of specificity of the male sex drive in this form.

The further question of *degree* of specificity opens up a broad field for further investigation. In the first place we should have to inquire as to whether the adequate stimulus was necessarily social. This would involve systematic comparisons between social and non-social incentives. Of the social incentives, we should next have to vary the factors of species, size, and sex. Finally, we might be led to compare the efficacy of receptive with non-receptive females. Although little discrimination between such sex-objects has been reported for the guinea pig (4, 6, 14), Louttit (7) has found differences in time required for an initial mount and also in time between mounts. He attributes such discrimination to the behavior of the female. Although smell is apparently not indispensable to sexual behavior in view of the work of Stone on rats (11) and rabbits (12) and his unpublished work on the guinea pig cited by Avery (4), it may, as Ishii (5) has suggested, aid in discrimination. More evidence is needed, however, to determine clearly the stimulus characteristics necessary to elicit sexual behavior.

E. Summary

The present experiment was designed to determine whether increased activity in the male guinea pig following sexual deprivation was specifically sex-directed.

Four mature males were studied in the hurdle box under each of the following conditions: (*a*) sexual deprivation with a female in-

centive; (*b*) sexual deprivation with an empty compartment incentive; (*c*) sexual satiation with a female incentive; (*d*) sexual satiation with an empty compartment incentive. The results showed a superiority of *a* over *c*, of *a* over *b*, and of *c* over *d*, while no difference was found between *b* and *d*.

These findings demonstrate the necessity of an external incentive to release the sex drive of the male guinea pig. The nature of the adequate stimulus presents a problem for further investigation.

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Department of Psychology
Connecticut College
New London, Connecticut

The Journal of Genetic Psychology, 1941, 59, 397-426.

THE EXTERNALIZATION OF DRIVE: III. MAZE LEARNING BY NON-REWARDED AND BY SATIATED RATS*[1]

Department of Psychology, Wilson College

E. E. ANDERSON

A. INTRODUCTION

In the first paper of this series (2) it was suggested that a drive such as hunger is originally aroused by internal conditions of the organism (e.g., hunger contractions) but that with continued usage the drive mechanism which leads to persistent and motivated behavior gradually becomes arousable by characteristics of the external situation, that is, the drive becomes externalized. It was further argued that once the drive has become arousable by the external situation it should be possible to use such an externalized drive in establishing an entirely new pattern of behavior. This characteristic would appear to differentiate the externalized or conditioned drive from the ordinary conditioned response. Specifically, the theory would lead to the implication that if the drive can be adequately externalized to the maze situation it should be possible to obtain the learning of an entirely new maze under conditions of no reward or of satiation, that is, under conditions which would ordinarily not lead to learning. The present experiment was designed to test whether or not it is possible to produce in rats a degree of externalization of drive adequate to result in the learning of a new maze where the normal hunger-reward conditions of motivation are not operating. The general procedure was to produce externalization of drive by giving rats a large number of trials in one maze, Maze *A*, under normal conditions of hunger and reward. The animals were then transferred to an entirely new maze, Maze *B*. On this second maze, some of the animals were hungry but never rewarded, others were satiated and received a reward, others were satiated but received no reward. According to the theory of externalization, some of these animals could be expected to learn Maze *B* under the conditions of no reward or of satiation. In order to control

*Received in the Editorial Office on September 2, 1940.

[1]The experimental work here reported was carried out in the psychological laboratories of Professor K. S. Lashley at Harvard University.

for the operation of unknown motivation such as "escape from the maze," "exploration," "return to the home cage," etc., control groups were used. These control animals were run under comparable conditions on Maze *B* but did not have the externalization trials on Maze *A*.

B. Performance of Externalized Animals upon a 6-Unit T-Maze

1. *Procedure*

The experimental animals were first given 73 trials on one maze, Maze *A*, under normal conditions of hunger and food reward. These trials were given in order to provide opportunity for the drive to become externalized to the maze situation itself and essentially were a preliminary preparation of the animals for the experimental conditions to be introduced with a second maze, Maze *B*.

a. Externalization training upon Maze A. Maze *A* was a 14-unit alley T-maze of the Stone pattern (true path sequence *RLLRRLRRLRRLLR*), painted black with manually operated doors to prevent retracing at each choice point. Black curtains were placed five inches from both sides of each choice point.

The animals were housed individually in small metal living cages throughout the experimental period, and were maintained upon a wet mash made of dog meal and water. Before training on Maze *A* was begun, the rats were given a preliminary orientation period. This consisted of a period of 11 days during which the animal's body weight was gradually reduced to, and maintained at, 80 per cent of his weight before food had been removed. The reduction in body weight was accomplished by restricting the length of the daily feeding period (8 to 15 minutes eating per day proved to be adequate). Then followed seven days during which the animals were given a total of 11 trials in a straight runway six feet long, with curtains and doors in place for the last eight trials. Training upon Maze *A* was begun at the conclusion of the above described preliminary training.

A total of 73 trials, distributed one per day, were given on Maze *A*; for all of these trials the animals were hungry and received a food reward at the end of the maze. Twenty-six pigmented male rats between three and four months of age were started on Maze *A*. Twenty of these rats satisfied the learning criterion of at least five

consecutive perfect trials within the first 61 trials; six rats not reaching this criterion on Maze *A* were discarded because there seemed some doubt that adequate externalization would have taken place in these six rats.

A rest period of two weeks was introduced after Trial 61. During these two weeks an adequate supply of food and water was in the living cages at all times. A new base weight was then taken and food removed. For 10 of the animals, the weight was then brought down to and maintained at 80 per cent of this new basal weight, the other 10 animals were allowed to eat for one hour a day. Trials 62 to 73 on Maze *A* were therefore given to half of the animals under a restricted diet while the remaining half of the animals were allowed to eat for one hour after their daily trial on the maze. The animals which were allowed to eat for one hour daily were to become the satiated groups on Maze *B* and the present procedure was used in order to avoid the satiation shock effect mentioned elsewhere (3). The training on Maze *A*, therefore, provides a period for the externalization of drive and also for the preparation of the satiated animals.

b. Experimental procedure for Maze B. After the completion of the 73 preliminary externalization trials on Maze *A*, the animals were transferred to Maze *B* and trained under various conditions of motivation. Maze *B* was a 6-unit alley T-maze with a pattern of choices the opposite of the first six choices of Maze *A* (true path sequence, *LRRLLR*). For the training on Maze *B*, the 20 animals were divided into four groups of five rats each as follows:

Group 1-HR; hungry rewarded. These animals were trained on Maze *B* under the same conditions which had been used for Maze *A*, i.e., maintained at 80 per cent of the base body weight and received a food reward at the end of the maze on the completion of each daily run.

Group 2-HNR; hungry non-rewarded. The animals of this group were maintained at 80 per cent their base body weight and were given their daily trial on Maze *B* when hungry. A reward was never in the food box of the maze at the end of the run.. The daily ration of each rat was given in a small individual eating box (not the reward box of the maze and differing from it in dimensions and construction) one to two hours after the completion of its daily run on the maze. This delay in feeding was introduced

to avoid the possibility of learning due to an immediate transfer of the animal from the reward box of the maze to the eating box. During the delay period the rats were returned to their living cages.

Group 3-SR; satiated rewarded. During the last 12 trials on Maze *A* these animals had been allowed to eat for one hour daily; this same eating period was maintained for the first 27 trials of Maze *B*, but the daily run in the maze was given immediately *after* the one hour eating period. Relatively complete satiation was thus produced. That the one hour period was adequate to do this is indicated by the fact that the average body weight of these five animals before food was removed from the cage after the rest period was 323 grams; two weeks later, on the first trial on Maze *B* and after the animals had been on this one hour eating schedule for the two weeks, the average body weight at the time of the maze trial was 369 grams. This increase in body weight continued throughout the period on Maze *B*. The average weight at the twenty-seventh trial (when a change in the method of satiation was introduced) on Maze *B* was 389 grams. A food reward was present in the reward box at the end of the maze although the animals of this group rarely ate it. After Trial 27, the method of satiation was changed. Instead of eating of the wet mash for one hour daily immediately preceding the maze trial, dry dog biscuit was placed in the animal's living cage so that food was present at all times.

Group 4-SNR; satiated non-rewarded. The animals of this group were satiated and received no food reward at the food box at the end of the maze throughout the training period on Maze *B*. Satiation was produced exactly as stated above for Group 3, including the change in procedure after Trial 27.

All animals of the above four groups were given one trial per day on Maze *B* for 37 days; for both of the hungry groups, the daily feeding period was delayed one to two hours after they had completed their maze trial. Both of the satiated groups were fed for one hour immediately preceding the maze trial up to the twenty-seventh trial; thereafter, food was in the living cage at all times. Two new reward boxes, neither of which had been used for Maze *A*, were used for Maze *B*, one being used for the rewarded groups and the other for the non-rewarded groups. Thus no food odors were present in the food box of the non-rewarded groups. An error

was counted if the animal entered a blind alley up to the black curtain (approximately ¾ body length) and only one error in a given blind was counted on any one trial.

c. Special procedures in cases of failure to run. Some cases of failure to run occurred in certain of the above groups, especially in the satiated groups. The following special procedures were used to facilitate the handling of the sluggish animals. The same procedures were also used when necessary with animals in the control groups to be described later.

1. If the animal had not left the starting box within one minute, he was gently pushed out into the maze and the door to the starting box closed to prevent the animal's return to it.
2. If the animal had not completed the maze run within 10 minutes of the time of entry into the maze itself, he was removed from the maze and the trial was counted a failure unless he was in motion at that time, in which case he was given a few more minutes.
3. If a rat thus failed to complete his run in 10 minutes on three consecutive days, the rat was called a failure and no further attempt was made to run him.
4. Some rats ran through the maze in a relatively short time but did not want to enter the reward box at the end of the maze. Instead of entering they would return to the last blind alley and sit for varying periods of time. If the animal had not entered the reward box within two minutes of the first approach to it, he was removed from the maze. Since such animals had essentially completed their run and had made all the errors on that trial which it was possible for them to make (doors prevented retracing) they were continued on the maze until such a time as they might show failures as defined in Points 2 and 3.

2. *Results for the Externalized Animals upon the 6-Unit Maze B*

Since the 73 trials on Maze *A* were essentially preliminary trials intended to produce externalization of drive, curves for the learning of this maze are not presented. The performance of the animals on Maze *A* was the normal learning performance expected from animals which are motivated by hunger and given a food reward. The learning curves for the four experimental groups run under

varying conditions on Maze *B*, the 6-unit maze, are presented in Figure 1. The curves were constructed by averaging groups of

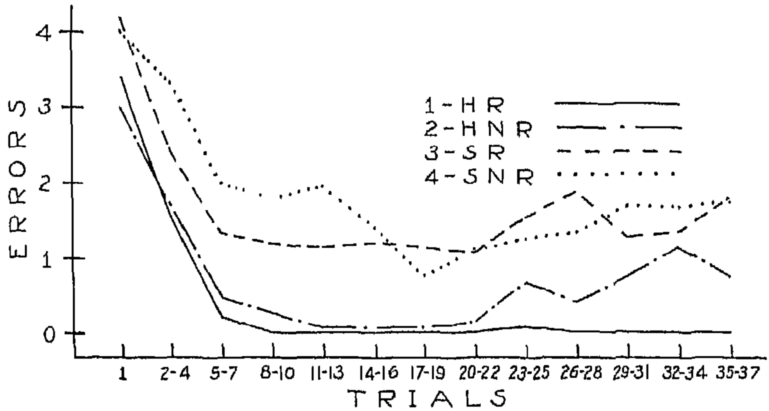

FIGURE 1

PERFORMANCE OF EXTERNALIZED GROUPS ON THE 6-UNIT MAZE *B*

three trials after the first trial, and are thus smoother than a curve would be if based on individual trials. Group 1, the hungry rewarded group shows a rapid and normal learning of this maze. Group 2, hungry non-rewarded, learned the maze almost as rapidly as did Group 1, but there is a tendency for the errors to increase after Trial 20. The curves for Groups 3 and 4, satiated rewarded and satiated non-rewarded, show a rather marked improvement in performance, although the average does not fall much below one error per trial on any three trials. The satiated animals receiving a reward appear to learn somewhat more rapidly than the satiated animals not receiving a reward. There is some tendency for the error scores of both these satiated groups to increase after about the twentieth trial. One animal of the satiated non-rewarded group failed to run after the eleventh trial, the curve for the remaining trials is thus based upon four rats. In all the other groups, every animal completed its 37 trials without failure to run on a single trial. All animals of Group 1, the hungry rewarded group, attained a criterion of three consecutive perfect trials; the range of trials to reach this criterion (not including the criterion trials) was two to six trials. All animals of the hungry non-rewarded group also at-

tained the criterion within a few trials, the range of trials being 2 to 11. One animal of the satiated rewarded group reached the criterion of learning in 14 trials, two animals of the satiated non-rewarded group in 5 and 14 trials. The remaining animals of the two satiated groups did not attain the learning criterion of three consecutive perfect trials in the 37 trials given on Maze *B*.

C. Performance of Externalized Animals upon a 12-Unit Double-Alternation T-Maze

Some of the rats performed so well upon Maze *B* that it seemed desirable to determine whether or not they would learn another and more difficult maze, still under conditions of no reward or of satiation. Therefore, immediately after the completion of the 37 trials on Maze *B*, the experimental animals were regrouped and transferred to Maze *C*.

1. *Procedure*

Maze *C* was a 12-unit T-Maze, alley type, of a double alternation pattern (true path sequence, *RRLLRRLLRRLL*), the maze was varnished, retracing doors and black cloth curtains were placed as in Mazes *A* and *B*. The rats did not all learn Maze *C* under the same condition of motivation as for Maze *B*. The re-groupings used for Maze *C* are described below. New numbers have been assigned to these groups but it should be recognized that the 20 rats of Groups 5 to 8 below are the same animals that had received 73 trials on Maze *A* under normal conditions of hunger motivation and 37 trials on Maze *B* under various conditions of motivation.

Group 5-HNR; hungry non-rewarded. This group contained the animals of Group 1-*HR* of Maze *B*. The difference here is that on Maze *C* the animals received no reward while they had received a reward on Maze *B*. This group was used in order to determine whether or not the additional hungry rewarded trials of Maze *B* would increase the degree of externalization of drive and thus greatly facilitate the learning of Maze *C*.

Group 6-HNR; hungry non-rewarded. The animals of Group 2-*HNR* of Maze *B* were used here and the same conditions of hunger and no reward were continued in Maze *C* as had been used for these animals on Maze *B*.

Group 7-SNR; satiated non-rewarded. Three rats from Group

4-*SNR* and two rats of Group 3-*SR* of Maze *B* formed this group. From the two satiated groups of Maze *B*, groups 3 and 4, the five rats which had shown the greatest willingness to run in Maze *B* under conditions of satiation were selected for this present Group 7. For the learning of Maze *C*, satiation was produced by having dog biscuit available in the living cages of the animals of this group at all times. Only one satiated group was used on Maze *C*, primarily because it was feared that animals which had been sluggish in running Maze *B* under conditions of satiation would refuse to run the longer and more difficult Maze *C*.

Group 8-HR; hungry rewarded. The remaining two rats of Group 4 and the remaining three rats of Group 3 which had not been selected for the above Group 7 were included in this group. Immediately after their last trial on Maze *B*, food was removed from these animals and they thus learned Maze *C* under normal conditions of hunger and reward.

The general and special procedures described under the procedure for Maze *B* were also used for Maze *C*. A total of 40 trials, distributed one per day, was given on Maze *C*.

2. *Results for the Externalized Animals upon the 12-Unit Maze C*

The learning curves for the four experimental groups on Maze *C*, the 12-unit double-alternation maze, which was the second maze learned under various conditions of motivation, are presented in Figure 2. The two non-rewarded groups and the satiated group all show about the same speed of learning up to about the twenty-fifth trial where the curve for the satiated group swings upward to an increasing number of errors as the trials on the maze continue. One animal of the satiated non-rewarded group, Group 7, refused to run after the eighth trial, the rest of the curve is thus based upon four animals. Of these remaining four animals, three reached the criterion of learning (three consecutive perfect trials) in 18 to 26 trials, one continued running but did not attain criterion in the 40 trials given on Maze *C*. There were two hungry non-rewarded groups on Maze *C*; two animals of each of these groups reached criterion in 10 and 31 trials (Group 5) and in 13 and 33 trials (Group 6), the remaining three animals of each group did not attain the learning criterion in the 40 trials given. It would be expected that all the animals of Group 8, the hungry rewarded

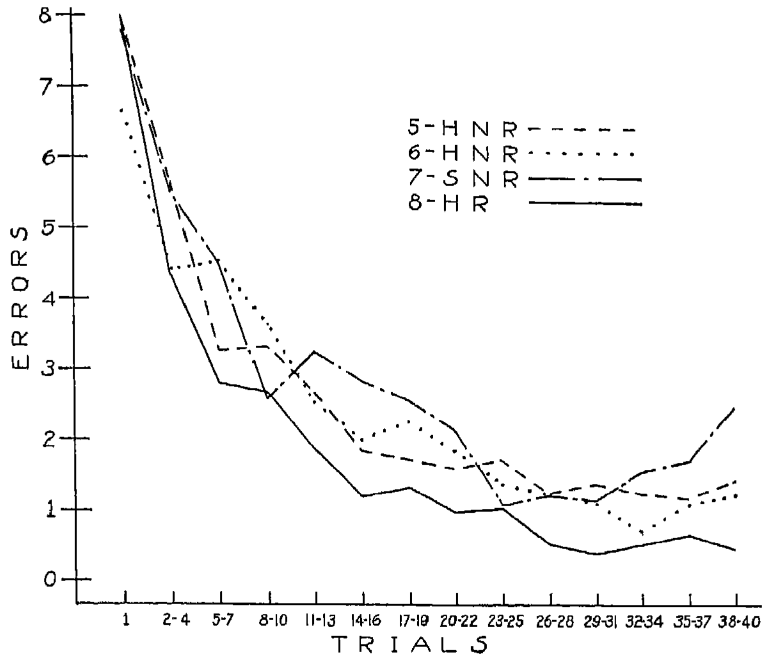

FIGURE 2
PERFORMANCE OF EXTERNALIZED GROUPS ON THE 12-UNIT DOUBLE ALTERNATION MAZE *C*

group, would learn this maze; four of the animals did reach criterion in from 5 to 14 trials but the fifth animal of this group did not learn the maze in the 40 trials.

The performance of some of the animals of the satiated and hungry non-rewarded groups is quite remarkable. Having been on Maze *B* for 37 trials under conditions of motivation which do not ordinarily lead to learning, certain of these rats proceeded to learn the difficult Maze *C* under conditions of satiation or no reward in a number of trials that falls within the range of animals learning Maze *C* under normal conditions of hunger and reward. The satiated group and the non-rewarded groups as a whole are inferior to the hungry rewarded animals of Group 8, but this inferiority is not as great as might have been expected. This last comparison is somewhat unsatisfactory, however, for after Trial 14 most of the

errors of the hungry rewarded Group 8 were made by the one rat which failed to learn the maze.

D. Performance of Control Animals upon a 6-Unit T-Maze

The control groups were used to determine the performance on animals on Maze *B* which had not had the externalization trials on Maze *A*. After a short preliminary training period during which the animals were adapted to the feeding schedule and the handling procedures necessary for maze work, the control animals were immediately trained upon Maze *B* under conditions comparable with those used for the experimental Groups 1 to 4 (Maze *B*) without, however, having had the 73 externalization trials on Maze *A*. It is of course possible that the preliminary training described below for the control groups resulted in some externalization of drive, but it seemed more desirable to allow some externalization to occur during the preliminary training than to attempt running non-rewarded and satiated animals upon a maze without any preliminary adaptation at all.

1. *Procedure*

Twenty pigmented male rats of approximately the same age as the animals of the externalized groups were used in the control experiments.[2] All of the animals of the control groups were placed on a restricted diet for 11 days, and their body weight gradually reduced to 80 per cent of the weight before food had been removed as described in the procedure for the externalized groups. Five trials, one per day, on a 6-foot straight runway with curtains in place the last two trials were then given; after which, 10 of the rats were continued on the restricted food schedule with body weight maintained at 80 per cent and were given three more daily trials on the curtained runway. The remaining 10 rats were satiated after the fifth trial on the straight runway and were thereafter allowed to eat for one hour a day. Three more daily trials on the straight runway were given to these animals immediately before the daily feeding period of one hour. This latter group of 10 animals was thus being prepared to become the satiated groups for Maze *B*.

[2]Two of the animals died during the course of the experiment.

After the above described preliminary training had been given, the 20 animals of the control groups were divided into the four groups described below and given 70 trials, one per day, on Maze *B* under various conditions of motivation. Maze *B* was the same 6-Unit T-maze which had been used for the externalized animals.

Group C1-HR; hungry rewarded. The five animals of this group were run on Maze *B* under normal conditions of hunger and food reward.

Group C2-HNR; hungry non-rewarded. The five animals of this group were run on Maze *B* when hungry, but no reward was ever present in the reward box at the end of the maze. This is the control group for Group 2-*HNR* of the externalized animals on Maze *B*.

Group C3-SR; satiated rewarded. The five animals of this group were satiated and a food reward was present in the food box at the end of the maze. Satiation was produced as described for the externalized rats on Maze *B*, i.e., the animals ate a wet mash made of powdered dog biscuit for one hour before the daily run on the maze up to the twenty-seventh trial; thereafter, satiation was produced by having dry dog biscuit in the animal's cage at all times. This group is the control for Group 3-*SR* of the externalized animals on Maze *B*.

Group C4-SNR; satiated non-rewarded. The five animals of this group were given the 70 trials on Maze *B* with satiation produced as described for Group *C3*; no reward was ever present in the food box of the maze. This Group C4-*SNR* is the control for Group 4-*SNR* of the externalized rats on Maze *B*.

The general precautions concerning the delayed feeding of the hungry groups and the use of different reward boxes for rewarded and non-rewarded animals and the special methods for handling sluggish animals were all used with the control groups exactly as described for the externalized groups.

2. *Results for the Control Animals on the 6-Unit Maze B*

The learning curves for the four control groups on Maze *B* are presented in Figure 3. As is to be expected, the hungry rewarded control group, Group *C*1, shows a normal, although somewhat slow, learning performance. One of the animals of this group died after the twenty-fifth trial, the latter part of the curve is therefore based on four animals. All the animals of Group *C*1 (including

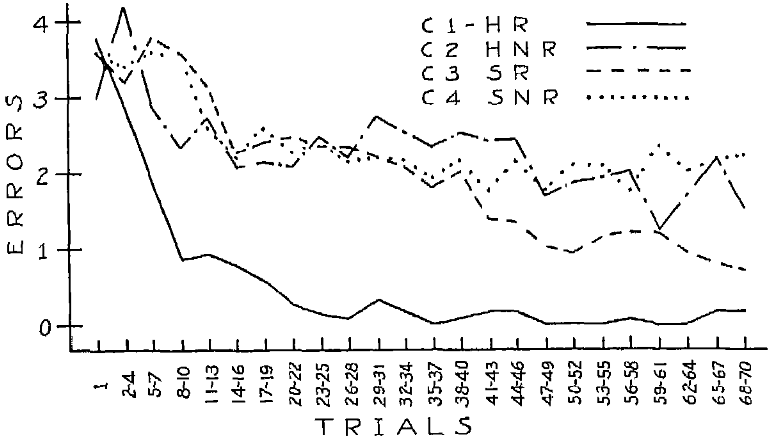

FIGURE 3

PERFORMANCE OF THE CONTROL GROUPS ON THE 6-UNIT MAZE *B*

the rat which died) reached a criterion of three consecutive perfect trials in from 4 to 23 trials (not including the criterion trials). Group *C*2, hungry rewarded and Group *C*4, satiated non-rewarded show some improvement in performance for the first 12 trials but then apparently reach a plateau and fluctuate around a mean error per rat per trial of about two errors. One rat of both these groups learned the maze, the animal of Group *C*2 reached criterion in 58 trials and that of *C*4 in 36 trials; one animal of Group *C*2 died after Trial 32. The learning curve for Group *C*3, satiated rewarded animals, parallels the curves of Groups *C*2 and *C*4 for about the first 30 trials and then the performance gradually improves until the average error score is less than one error per rat per trial. The improvement in this satiated rewarded group is probably due to food preference. For the first 27 trials, the animals of this group were satiated by eating a wet mash one hour before the maze trial, the wet mash was also used as the reward at the end of the maze. After Trial 27, however, the animals were satiated by being allowed access to dry dog biscuit at all times The reward in the maze continued to be the wet mash and the preference for this mash probably accounts for the drop in the learning curve after the twenty-eighth trial. Two animals of this satiated rewarded

group reached criterion in 32 and 45 trials. There were no cases of refusal to run in any of the control groups.

E. Performance of Control Animals upon a Second 6-Unit T-Maze

Animals of the externalized groups were given 73 trials on the 14-unit Maze *A* and were then given 37 trials under various conditions of motivation upon the 6-unit Maze *B*. The control animals were given 70 trials upon Maze *B* under comparable conditions of motivation but without any previous maze training. A comparison of the first 37 Maze *B* trials of the control groups with the 37 trials of the externalized groups upon Maze *B* would therefore indicate whether or not the training upon Maze *A* had influenced the performance on Maze *B*. If the Maze *A* training should prove to facilitate the learning on Maze *B* the results could not be interpreted unambiguously since the effect upon the performance on Maze *B* might be due to (*a*) the fact that the animals had received many *motivated and rewarded* trials on Maze *A* (the interpretation desired for the theory of externalization), or (*b*) the fact that the animals had been in a previous maze for a large number of trials, the matter of motivation being unimportant. It is clear that this ambiguity in interpretation can be avoided by using as a further control a group of animals that has had a large number of trials on one maze under anomalous conditions of motivation and is then tested upon a second maze under the appropriate conditions of motivation. After the completion of the 70 trials upon Maze *B*, therefore, the control animals were transferred to a new 6-unit Maze *D* (comparable in difficulty to Maze *B*) and tested under various conditions of motivation. One group was run under conditions of hunger and reward to determine the normal performance on the second maze; two groups were used to aid in determining which of the above suggested interpretations might be correct, and one group was used to study an additional problem to be described later.

1. *Procedure*

Maze *D* was a 6-unit T-Maze similar in all respects to Maze *B* except that the sequence of choices was the reverse of the sequence in Maze *B*. That is, the true path sequence for Maze *D* was *RLLRRL*. The animals were given one trial per day on Maze *D*

for 36 days. General and special procedures were as described for the externalized groups. The animals of the control groups *C*1 to *C*4 were regrouped for Maze *D* and were run under the conditions described below.

Group C5-HNR; hungry non-rewarded. The four animals of Group *C*1-*HR* (one animal of *C*1 died after Trial 25 on Maze *B*) which had learned Maze *B* under normal conditions of hunger and reward form the present hungry non-rewarded group. Since some externalization should have occurred during the rewarded trials upon Maze *B*, the present group is essentially an externalized group. It differs from the externalized Group 1-*HNR* in that its externalization trials were on the 6-unit Maze *B* while the externalization of Group 1 occurred on the 14-unit Maze *A*. A comparison of the two groups should thus indicate the effect of the amount of maze experience, as determined by the length of the maze, upon externalization.

Group C6-HNR; hungry non-rewarded. This group contains the four animals of Group *C*2-*HNR* (one animal of *C*-2 died after Trial 32 on Maze *B*) which ran Maze *B* under conditions of hunger and no reward. The same conditions were continued for Maze *D*. Group *C*6 is one of the groups used to determine the effect of a large number of trials on one maze under anomalous conditions of motivation upon the performance on a second maze in the absence of normal motivational conditions.

Group C7-SNR; satiated non-rewarded. The five animals of Group *C*4-*SNR* which ran Maze *B* under conditions of satiation and no reward were tested on Maze *D* under the same motivational conditions. Satiation was produced by having dog biscuit present in the animals' living cages at all times. This group is also used to determine the effect of a large number of trials in one maze under anomalous conditions of motivation on the performance of the animals in a second maze.

Group C8-HR; hungry rewarded. The five animals which had been satiated and rewarded on Maze *B* (Group *C*3-*SR*) were made hungry at the conclusion of their 70 trials on Maze *B* and learned Maze *D* under normal conditions of hunger and reward.

2. *Results for the Control Animals upon the 6-Unit Maze D*

The learning curves for the control groups on the second maze upon which they were tested, i.e., Maze *D*, are presented in Figure

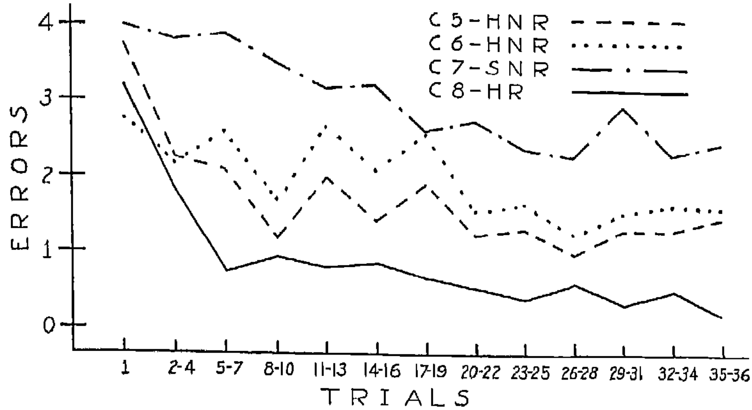

FIGURE 4

PERFORMANCE OF THE CONTROL GROUPS ON THE 6-UNIT MAZE *D*

4. The hungry rewarded group, Group *C*8, shows marked improvement in performance up to about the seventh trial and then the curve flattens considerably. This slowing in the curve was due to one rat in the group which failed to learn the maze in the 36 trials given. The other four rats of Group *C*8 reached the learning criterion of three perfect consecutive trials in 5 to 18 trials (exclusive of the criterion trials). The error curves for the two hungry non-rewarded groups *C*5 and *C*6 fluctuate noticeably, but gradually drop to an average error per trial (based on three trial units) of from 1 to 1.5 errors. Group *C*5 had received externalization trials upon Maze *B* and should therefore be superior to Group *C*6. As the curve shows, *C*5 is consistently better than *C*6 but the difference is not very large. One of the four rats in each of the hungry non-rewarded groups reached criterion, that of *C*5 in 28 trials and that of *C*6 in 24 trials; the remaining three animals of each group did not learn the maze in the 36 trials given. The error curve for Group *C*7, satiated non-rewarded shows relatively little improvement. None of the animals of this group reached criterion. Three of the animals failed to run, one after the sixth trial, another after Trial 16 and the third after Trial 30; thus the curve for Group *C*7 is based upon varying numbers of rats. Of the two remaining rats, one refused to run on a number of scattered trials but did not refuse to run for three consecutive days (the criterion of failure).

F. Comparison of the Results of the Externalized and Control Groups

The learning curves presented in Figures 1 to 4 have shown the marked improvement in performance of the externalized groups run under anomalous conditions of motivation. The control groups run under anomalous conditions of motivation without the previous externalization show some improvement in performance but it is much less than that for the externalized groups. To facilitate the comparison between the externalized and control groups run under comparable conditions of motivation, the cuives of Figures 1 to 4 have been re-grouped according to the motivational conditions and are presented in Figures 5 to 8.

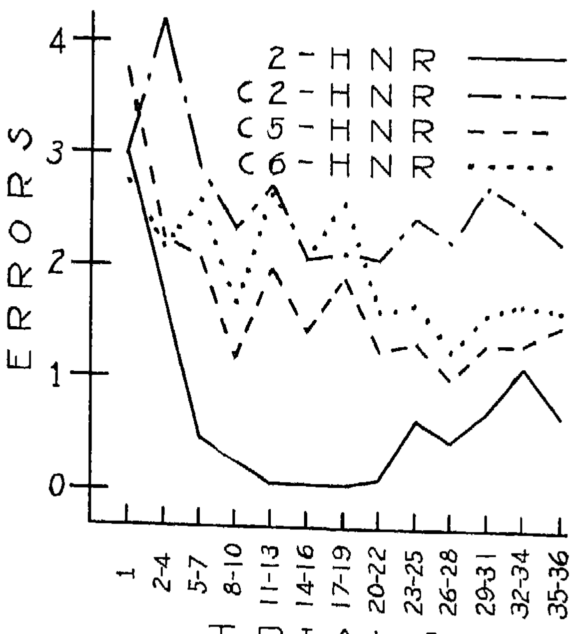

FIGURE 5

Comparison of the Performance of the Externalized Groups 2 and *C5* with That of the Control Groups *C2* and *C6*

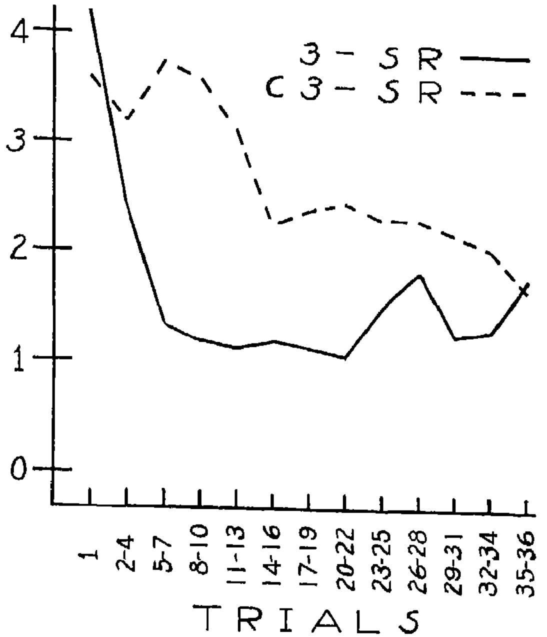

FIGURE 6

COMPARISON OF THE PERFORMANCE OF THE EXTERNALIZED GROUP 3 WITH THAT OF THE CONTROL GROUP *C*3

1. *The Effect of Previous Maze Training As It Affects Learning under Various Conditions of Motivation*

Learning curves for all groups which were run under conditions of hunger and no reward on Mazes *B* and *D* are presented in Figure 5. Group 2 which had had 73 rewarded trials on Maze *A* is clearly superior to the control Group *C*2. Group *C*6 which represents the performance of Group *C*2 when it was transferred to Maze *D* after 70 trials on Maze *B* is also inferior to Group 2. Group 2 is even superior to the externalized Group *C*5 which had been given 70 hungry rewarded trials on Maze *B* before the *HNR* training on Maze *D* shown in the curve. The superiority of Group 2 over Group *C*5 may indicate that externalization trials on the 14-unit Maze *A* are much more effective than externalization trials on the small 6-unit Maze *B*. Group *C*5 which had externalization

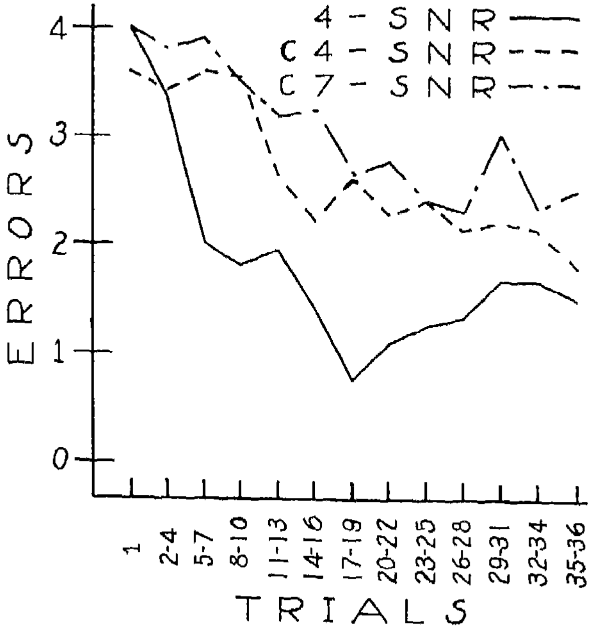

FIGURE 7
COMPARISON OF THE PERFORMANCE OF THE EXTERNALIZED GROUP 4 WITH THAT OF THE CONTROL GROUPS *C*4 AND *C*7

trials on Maze *B* is superior to both Group *C*2 and *C*6 but the superiority is not marked. Group averages for several measures are presented in Table 1. The data in the table are based upon the first 36 trials on each of the mazes used in this study. The superiority of the externalized Group 2-*HNR* over the *HNR* control groups is clearly shown in the table. The externalized Group *C*5 is also somewhat superior to the control groups *C*2 and *C*6 in most of the measurements presented in the table.

The curves for the two satiated rewarded groups on Maze *B* are presented in Figure 6. The externalized Group 3 is clearly superior to the control Group *C*3 in the early trials. It was suggested above that the drop in the curve of *C*3 in the later trials was due to a food preference when the method of satiation was changed after Trial 27. This same type of explanation cannot account for the

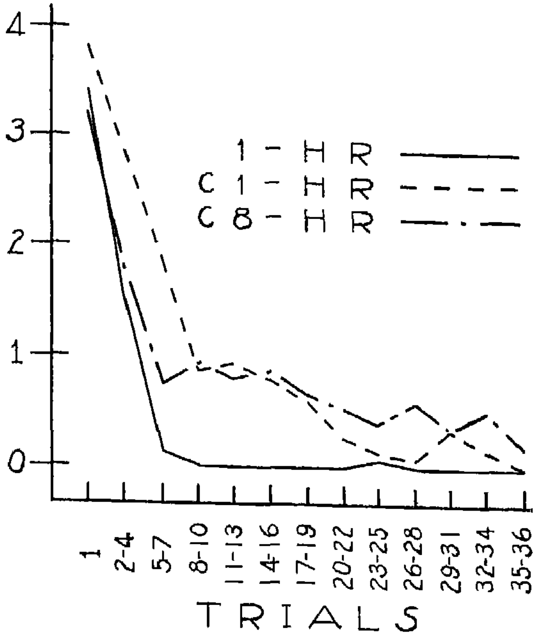

FIGURE 8
COMPARISON OF THE PERFORMANCE OF THE EXTERNALIZED GROUP 1 WITH THAT OF THE CONTROL GROUPS *C*1 AND *C*8

early drop in the curve of Group 3 since the animals of this group attained their best perfoimance in the first seven trials on the maze and befoie the change in satiation was introduced. The superiority of Group 3 over Group *C*3 during the first 36 trials on the maze is also indicated by a compaiison of the figures in Table 1.

The curves for all the satiated non-rewarded groups aie presented in Figure 7. The superiority of the externalized Group 4 over the control Groups *C*4 and *C*7 is clearly indicated by the curve in the figure and is also evident in Table 1.

A fuither comparison may be made by combining the various externalized and control groups. Four groups (19 rats) of externalized animals weie tested on the small mazes *B* and *D* under conditions of no reward or satiation (Groups 2, 3, 4, *C*5). Nine of the 19 rats (47 per cent) reached the criterion of three consecu-

TABLE 1

COMPARISON OF THE MAZE PERFORMANCE OF EXTERNALIZED AND CONTROL ANIMALS TRAINED UNDER VARIOUS CONDITIONS OF MOTIVATION

All values are calculated on the basis of the first 36 trials in the maze. *HR* = hungry, rewarded; *HNR* = hungry, non-rewarded; *SR* = satiated, rewarded; *SNR* = satiated, non-rewarded. Maze *B* = 6-unit T-maze; Maze *C* = 12-unit T-maze; Maze *D* = 6-unit T-maze (the mirror image of *B*). Criterion = three consecutive perfect trials.

Group	Motivation	*N*	Externalized or control	Maze	Number reaching criterion	Ave. no. perfect trials	Ave. total errors	Time secs.
1	*HR*	5	Externalized	*B*	5	32.6	8.8	386
*C*1	*HR*	5[a]	Control	*B*	5	21.8	30.2	676
*C*8	*HR*	5	Control	*D*	4	21.2	28.2	463
2	*HNR*	5	Externalized	*B*	5	21.8	21.8	1181
*C*5	*HNR*	4	Externalized	*D*	1	7.0	58.0	3150
*C*2	*HNR*	5[b]	Control	*B*	0	2.0	90.6	2428
*C*6	*HNR*	4	Control	*D*	1	4.5	71.8	3626
3	*SR*	5	Externalized	*B*	1	5.6	54.2	4575
*C*3	*SR*	5	Control	*B*	1	1.8	95.8	5481
4	*SNR*	5	Externalized	*B*	2	9.6	58.8[c]	2315
*C*4	*SNR*	5	Control	*B*	0	1.4	94.4	3422
*C*7	*SNR*	5	Control	*D*	0	.0	96.0[d]	11743
8	*HR*	5	Externalized	*C*	4	19.8	62.4	812
5	*HNR*	5	Externalized	*C*	2	6.6	88.0	3277
6	*HNR*	5	Externalized	*C*	2	6.6	86.0	3975
7	*SNR*	5	Externalized	*C*	3	5.4	95.0[c]	6457

[a]One animal died after trial 25. Since this animal had reached the criterion of learning and had made no errors since Trial 4, his results have been included.
[b]One rat of this group died after Trial 32 but his results are included.
[c]One animal refused to run at some stage of training. This average, therefore, is based on four animals.
[d]Three animals refused to run at some stage of training. This average, therefore, is based upon the two animals that completed 36 trials.

tive perfect trials within 36 trials. Five groups (23 rats) of the control animals (Groups *C*2, *C*3, *C*4, *C*6, *C*7) were tested on the small mazes under comparable conditions; only two of the control animals (9 per cent) reached the criterion level within 36 trials.

Although the superiority of the externalized groups appears evident, some doubt may arise from the fact that, as mentioned

earlier, six animals were discarded during the externalization trials upon Maze *A* because they had not learned that maze. The theory of externalization does not imply that the process can be readily obtained in all animals, and it was considered improbable that externalization would occur in rats which had not learned Maze *A* within 61 trials. Therefore, six rats (of 26) which had not reached a criterion of five consecutive perfect trials within 61 trials on Maze *A* were discarded and not subjected to the experimental procedures. On the other hand, the control animals, of necessity, had no previous training on mazes which might serve as a basis for making a comparable selection and therefore were unselected. It seems highly improbable to the writer that the superiority of the externalized groups can be attributed to the selection of the animals for the following reasons.

1. If a comparison is made on the basis of the total errors made in the first 36 trials of Mazes *B* and *D*, practically no overlapping is found between the comparable externalized and control groups. The rats of Group 2-*HNR* made 12 to 33 errors in 36 trials, while rats of the control Group *C2-HNR* and *C6-HNR* made 66 to 137 and 36 to 108 errors, respectively, in 36 trials. Group 3-*SR* made 26 to 66 errors while the range for the comparable control Group *C3-SR* was 76 to 132 errors. Only in the satiated non-rewarded groups did any overlap occur: three rats of the externalized Group 4-*SNR* made 14 to 54 errors, one rat made 116 errors, and one rat refused to run after Trial 12. The five animals in the control Group *C4-SNR* made from 66 to 120 errors, while in Group *C7-SNR*, three rats refused to run (after 5, 16 and 30 trials) and the remaining two animals made 91 and 101 errors. Thus, practically every rat of the externalized Groups 2, 3, and 4 is superior to every rat of the comparable control groups. The writer does not see how the discarding of six rats during the externalization training on Maze *A* could possibly produce this relatively complete lack of overlapping between the externalized and control groups.

2. A second reason for doubting that the selective factor can explain the superiority of the externalized groups is that the anomalously motivated groups overlap considerably with the normal hungry and rewarded group among the externalized animals while no such overlapping is evident among the control animals; i.e., the control group which had normal learning motivation, the animals

hungry and receiving a reward, was far superior to the control groups with anomalous motivation. In contrast with this, the externalized group which had normal learning motivation overlapped considerably the externalized groups with anomalous motivation. Among the externalized groups, the animals of Group 1 ran Maze *B* when hungry and rewarded. These five animals learned Maze *B* in two to six trials (not including the criterion trials). In the externalized groups (19 rats, Groups 2, 3, 4, *C*5) run under anomalous conditions of motivation on Mazes *B* and *D*, four rats learned in two to five trials, five rats in 10 to 28 trials, and 10 rats failed to learn in the 37 trials given. There is thus considerable overlap between the hungry and rewarded externalized animals and the other externalized animals with no such motivation. In the control groups, on the other hand, no such overlapping between the hungry rewarded animals and those run under anomalous conditions is apparent. The two control groups *C*1 and *C*8 ran Mazes *B* and *D* with hunger and reward motivation. Nine of the 10 rats in these two groups reached criterion in from 4 to 23 trials; one rat in *C*8 did not learn the maze in the 36 trials given. In the five comparable control groups (24 cases) run under anomalous conditions of motivation there were five cases in which the criterion was reached in from 24 to 58 trials (only two of these learned in less than 36 trials), the criterion not being attained in the remaining 19 cases. Thus some animals of the externalized groups run under anomalous conditions of motivation learned as rapidly as did hungry rewarded animals which had a strictly comparable previous experience, while no animals of the control groups run under anomalous motivation learned as rapidly as did comparable animals run under conditions of hunger and reward. Selection cannot possibly account for this result since the comparisons are made within comparable populations.

The learning curves for the animals run in Mazes *B* and *D* under normal conditions of motivation, i.e., hungry and rewarded, are presented in Figure 8. Group 1 with previous experience on Maze *A* learned the small 6-unit maze more rapidly than either Group *C*1 or *C*8. The superiority of Group 1 is also indicated in the values presented in Table 1. In general, the hungry rewarded groups are superior to all groups run under anomalous conditions of motivation except that the externalized Group 2-*HNR* is as good as some of the groups run under conditions of hunger and reward.

The results for the second maze, the 12-unit Maze *C*, learned by the externalized groups are not strictly comparable to the results of the much easier 6-unit Mazes *B* and *D*. Yet Table 1 shows that for the number of animals reaching the criterion of three consecutive perfect trials and for the average number of perfect trials made in the 36 trials, the externalized groups run under anomalous conditions of motivation, Groups 5, 6, and 7, are superior to any of the comparable control groups on the much easier Mazes *B* and *D*.

2. *Experience on One Maze under Anomalous Conditions of Motivation as it Affects Performance on Another Maze*

The control animals were given 70 trials on Maze *B* under varying conditions of motivation and then transferred to Maze *D*, still with anomalous motivation. A comparison of the results on these two mazes should indicate whether or not long experience, as such, on a maze facilitates the performance on a second maze. Group *C6-HNR* is slightly better on Maze *D* than it had been on Maze *B* as Group *C2-HNR*. Group *C7-SNR* appears on the learning curves of Figure 7 to do about as well on Maze *D* as it had done on Maze *B* as Group *C4-SNR*, but it must be remembered that three animals of *C7* failed to run at some stage of their learning Maze *D*, thus the curve for *C7* is based on a decreasing number of animals as the trials increase. This fact in conjunction with the appropriate data in Table 1 would indicate that the previous *SNR* training on Maze *B* was actually detrimental to the performance on Maze *D*. Group *C1* learned Maze *B* under normal learning conditions of hunger and a food reward, Group *C8* learned Maze *D* under these conditions. The learning performance of these two groups is about the same, thus the previous trials Group *C8* had had on Maze *B* as Group *C3-SR* did not affect its performance on Maze *D*. In general, then, it appears doubtful that the 70 trials on Maze *B* under anomalous conditions of motivation had any consistent effect upon the later learning of Maze *D*.

3. *Limits to the Effect of Externalization*

Groups 5 and 6 were both trained on Maze *C* under conditions of hunger and no reward; both had originally had 73 rewarded trials on Maze *A*. Group 5 then received 37 hungry rewarded trials on Maze *B* while Group 6 received the 37 trials on Maze *B* under

conditions of hunger but no reward. A comparison of the learning curves of these two groups (Figure 2) and of the data presented in Table 1 shows the two groups to be quite equal in their performance upon Maze *C*. The additional 37 rewarded trials on Maze *B* (making a total of 110 externalization trials) did not, therefore, produce a greater degree of externalization in Group 5 than was present in Group 6 which had only the 73 externalization trials.

4. *Time Scores*

The superiority in time scores of the animals which have had previous externalization trials before being trained on mazes under conditions of no reward or of satiation over control animals that have not had such externalization trials is evident from the last column of Table 1. For this column, the median time score of each group for each trial was determined, and the data presented consist of the sums of these median time scores for the first 36 trials in each of the mazes. In general, the time scores do not yield normal learning curves, but fluctuate considerably and show some tendency to remain at a relatively constant level or, even, to become worse in the later trials. The tendency for the animals to become slower with increasing practice is especially noticeable in the satiated animals. The increased time scores in the later trials of such animals is due to an increasing slowness in starting to run the maze and an increased hesitation to enter the food box. In spite of the fact that the trials of satiated and non-rewarded rats tend to be slow, there were a number of trials in both non-rewarded and satiated groups that were made in approximately normal time. Such trials were indistinguishable, both as to accuracy and speed, from trials made by animals running under normal conditions of hunger and reward.

G. Discussion

The theory of externalization of drive implies that long continued training in a situation involving hunger motivation and a food reward (or other similar motivation) results in a change in the stimulus constellations which arouse the drive mechanisms and lead to motivated or persistent behavior. Originally, a drive such as hunger is probably aroused almost exclusively by internal condi-

tions;[3] but, as the organism becomes experienced in situations involving the drive thus aroused and its satisfaction, the drive gradually becomes arousable by characteristics of the external situation. The writer has termed this process the externalization of drive. If externalization were complete, it should be possible to obtain a highly motivated performance in the absence of the original internal conditions by merely presenting the organism with the appropriate situation. And even in cases where the externalization is not complete, it should be possible to obtain evidence of the arousal of motivated performance under conditions where the normal hunger-reward sequence is altered. In the present experiment, rats were given prolonged training on one maze, Maze *A*, under normal conditions of hunger and reward to produce externalization of drive. The animals were then trained on new mazes under various conditions of motivation. After externalizaton, some of the animals learned the new mazes under conditions of no reward or/and satiation in a number of trials that falls within the range for rats learning the same mazes under normal conditions of hunger and reward. Others learned the new mazes but more slowly than hungry rewarded animals; and some animals of the externalized groups failed to learn the new mazes to the criterion of three consecutive perfect trials. The externalized groups as a whole show marked improvement in performance and are clearly superior to the control groups which were run on mazes without previous externalization trials.

The writer believes that the results of the present experiment can be most adequately interpreted in terms of externalized drives but some alternative explanations deserve consideration.

1. It might be argued that the maze learning of the externalized animals was not due to the operation of any externalized drive but rather resulted from the presence of some relatively unknown source of motivation such as "escape from the maze," "return to

[3]It is to be noted that the drive or drive mechanism is not identified with the internal conditions such as stomach contractions, etc., which serve to arouse it. The theory assumes that stimuli resulting from such internal physiological states as are produced by food deprivation excite some neural (and perhaps glandular) mechanism or mechanisms which lead to the persistent behavior characteristic of motivated action. The drive might thus be more properly identified with this neural mechanism than with the internal state (which may be called a *need*). After externalization has taken place, it is assumed that the neural mechanisms involved are excited by external stimuli as well as by the internal state.

the home cage," "exploration," etc. If these are the motives they should have operated for the control groups which were trained on Mazes *B* and *D* without having had the externalization trials on Maze *A*. The externalized animals were much superior to the comparable control animals. It is recognized that this argument is not as strong as it might be because some selection was deemed necessary in the case of the externalized animals, but for the reasons given in Section *F*1 of this paper, it seems highly improbable that the superiority of the externalized groups can be accounted for in terms of the selection of groups.

2. It might be argued that the superiority of the externalized groups over the control groups is but an instance of positive transfer of training from Maze *A*. If by transfer is meant that mere experience or familiarity with one maze will facilitate the learning of a second maze, then the present experiment offers evidence of zero or even negative transfer. The control animals which had 70 trials on Maze *B* under anomalous motivation and were then transferred to Maze *D* under various motivating conditions represent instances in which long experience on one maze (but not normally motivated externalization trials) is followed by the learning of a second maze. As the results in Section *F*2 show, the transfer effect of general familiarity with a maze appears to be very slight or even negative. It is only when the experience upon the first maze is adequate to result in externalization of drive (i.e., involves normally motivated trials) that the performance upon the later mazes under anomalous conditions of motivation is markedly facilitated. The writer believes the facilitating effect of the externalization trials on a previous maze is too intimately concerned with the problem of motivation, in contrast with that of cognition or experience, *per se*, to be classified under the the broad and non-explanatory concept of transfer of training.

3. It might be argued that, instead of being due to externalization of drive, the results of the present experiment are due to conditioned response, to anticipation, or to conditioned reward. If by conditioned response is meant that certain specific responses such as "turn left here," etc., are associated with certain characteristics of the maze, the theory would be inadequate since the essential problem is to account for the establishment of a new sequence of responses. If, however, it is meant the characteristics of the maze come, in time,

to arouse the *drive* which leads to the learning of new mazes, then the difference between such a theory of *conditioned* drive and the theory of externalization of drive would appear to be one of terminology. The conditioned reward and the anticipation theories do not appear to be adequate for the following reasons. (*a*) New food boxes were used for the training upon the later mazes. (*b*) In her experiment upon conditioned rewards, Williams (6) found difficulty in demonstrating that a conditioned stimulus (food box) had a reward value and finally resorted to a latent learning procedure to demonstrate it; even then the conditioned reward lost its effect after a few trials. It would therefore seem improbable that a conditioned reward would last for the 37 trials on the externalized animals in Maze *B* and the 40 trials in Maze *C*. (*c*) The "anticipation" effect demonstrated by Elliot (4) is shown by a disturbance of performance when the reward conditions are altered, rather than by a continuation of performance. (*d*) The anticipation and conditioned reward theories under consideration would be forced to assume that the rats of the externalized groups can learn Maze *B* under anomalous conditions of motivation and then go on to learn the 12-unit Maze *C* (under similar conditions) yet not discover in all this time (a total of 77 trials) that there is no food in the reward box. (*e*) At best, the theories under consideration would explain the results of the hungry non-rewarded groups only and would require some other principle to account for the results of the satiated groups.

4. The last alternative explanation to be considered would argue that the externalization trials in Maze *A* built up an autonomous motive in the animals which thereafter could function more or less independently of the conditions which originally gave rise to it. The learning of the later mazes would thus be attributed to the operation of this autonomous motive. Since the writer considers the externalized drive to be essentially one kind of autonomous motive, there is no real conflict between interpretation in terms of autonomous motive and externalized drive. The autonomous motive appears to be a more general concept than that of externalized drive. The general implications and principles of Allport's theory of functional autonomy (1) would presumably apply to all classes of autonomous motives, but the special classes of motives, such as externalized drives, might show principles restricted to a given class alone.

A result in this experiment seems to be related to Allport's view that it is a habit in the making rather than a perfected habit which becomes an autonomous motive. The non-rewarded and satiated externalized animals learned Maze *B* quite rapidly but, with continued trials after learning, the errors increase somewhat (see Figure 1); when these animals were then transferred to the difficult Maze *C*, still unrewarded or satiated, there was again relatively rapid learning. Thus the externalized drive seems to be more effective in establishing a new habit than in maintaining an old habit once it has been perfected.

The results of the present experiment and the preceding discussion appear to justify the conclusion that training upon one maze under normal conditions of hunger and reward does something to the motivational systems of the organism so that the animals will then learn, or partially learn, other mazes in the absence of the normal rewarded hunger drive, and that this something that is done to the motivational system is essentially an externalization of drive, which is probably a special case of autonomous motive. The rest of the discussion will be concerned with several relatively minor problems.

There is some tendency for the hungry non-rewarded animals of the externalized groups to be superior to the satiated animals of the externalized groups although such superiority is not clear in the second maze, Maze *C*, learned by the externalized animals. This superiority may be due to the facilitating effect of the hunger condition *per se*, since Elliott and Treat (5) have shown that the presence of hunger contractions facilitates learning in a situation which does not involve the use of a hunger reward. Some interesting effects of the hunger condition which is not rewarded were shown in the following cases (an extra training not included in the results of this experiment): A total of five rats, all of them from satiated non-rewarded groups, failed to run at some stage of their training; that is, they had not completed their daily trial within a period of 10 minutes for three consecutive days. After such a failure occurred, the animal was made hungry and its trials on the maze continued under conditions of hunger but no reward. Of these five animals now running when hungry but not to a reward, three reached a criterion of three consecutive perfect trials in 2, 2, and 13 trials (exclusive of the criterion trials). The other two rats

showed improvement in performance but did not attain the criterion in the 20 *HNR* trials given. This effect is somewhat similar to latent learning, but in latent learning the introduction of a reward to hungry non-rewarded animals results in a marked drop in error score whereas in the present case the drop in the errors is produced when satiated non-rewarded animals are made hungry without the introduction of a food reward.

Four animals of the control groups run under anomalous conditions of motivation did attain the criterion of three consecutive perfect trials; two of these animals were in the satiated reward group and the learning can be attributed to food preference when the change in the method of satiation was introduced, but the learning of the remaining two animals cannot be as readily understood. One of these animals was in the *SNR* group and learned Maze *B* in 36 trials, the other was in the *HNR* group of Mazes *B* and *D* and reached criterion on both mazes in 58 and 24 trials respectively. This relatively rare performance of learning a maze without apparent motivation can be attributed to various factors such as escape from the maze, return to the home cage, gradual establishment of an autonomous motive, the principle of least effort (i.e., some tendency to learn and use the shortest path between any two given points), etc. At present there appears to be no basis for selecting any of these or other similar explanations and the present experiment offers no basis for a choice.

Experiments on latent learning have shown that an animal may learn the pattern of a maze even when he is not motivated to use that knowledge. The present experiment shows that it is possible to build up in the rat by appropriate procedures an adequate independent motivation to use this knowledge in the absence of normal motivating conditions. Thus, learning a maze under normal conditions of motivation not only provides an animal with knowledge of the maze and probably mazes in general, but also does something to the motivational systems of the organism; in the terminology of the present paper, it results in externalization of drive and the externalized drive can thereafter be used to produce a motivated performance which will result in the learning of other entirely different mazes.

H. Summary

Rats were given 73 trials in one maze under normal motivational conditions of hunger and reward. Different groups of these animals were then tested upon two different mazes under conditions of hunger, reward; hunger, no reward; satiation, reward; and satiation, no reward. Some of the animals run under the anomalous conditions of motivation learned the later mazes to a criterion of three consecutive perfect trials (in some cases as rapidly as animals run with normal hunger-reward motivation); the animals as a whole showed marked improvement in performance on these mazes. Control animals tested upon mazes under comparable anomalous motivation but without the previous hungry-rewarded maze trials, were, in general, clearly inferior to the experimental (externalized) groups. The results are interpreted in terms of the theory of externalization of drive.

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Department of Psychology
Wilson College
Chambersburg, Pennsylvania

The Journal of Genetic Psychology, 1941, **59**, 427-436.

BOOKS

The *Journal of Genetic Psychology*, the *Journal of General Psychology*, and the *Journal of Social Psychology*, will buy competent reviews at not less than $2 per printed page and not more tran $3 per printed page.

Conditions. Only those books that are listed below in this section are eligible for such reviews. In general, any book so listed contains one or more of the following traits: (*a*) Makes an important theoretical contribution; (*b*) consists largely of original experimental research; (*c*) has a creative or revolutionary influence in some special field or the entire field of psychology; (*d*) presents important techniques.

The books are listed approximately in order of receipt, and cover a period of not more than three years A reviewer must possess the Ph.D. degree or its equal in training and experience.

Procedure. If among the books listed below there is one that seems important to you, you are invited to write a review of that book. It is not necessary to make arrangements with the Editor. Just send in your review. It does not matter if the book in question has been reviewed before.

(1939)

ROSETT, J. The Mechanism of Thought, Imagery, and Hallucination. New York: Columbia Univ. Press, 1939. Pp. 289.

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CRITICAL REVIEWS OF RECENT BOOKS

(Werner, H. Comparative Psychology of Mental Development. New York: Harper, 1940. Pp. 510.)

REVIEWED BY DAVID RAPAPORT

Since Kant's *Critique of Pure Reason* there were many pros and cons as to whether we shall ever learn the nature of the world of objects or shall always remain bound to the world of phenomena—to the world as it appears to us. It was inevitable that psychologists adopt now this, then the other philosophical view. The progress of psychological research, however, followed a consistent line. It asked how we perceive, how we act, etc.; because perceiving, reasoning, remembering and acting reflect how the world of living beings is built. Psychology came into the possession of a steadily increasing number of data showing that the world of each individual human being differs from that of others—and that these worlds of "normal" human beings generally differ from the world of the feeble-minded, the brain-injured, the psychotic, etc., as well as from that of the human child. Again the worlds of human beings, including all varieties, differ from those of animals, which, in their turn, differ among themselves. Every living creature experiences its world differently, the active extreme of this being man's research and the passive extreme the vegetative passive existence of plant-like animals—depending on the psychophysical organization of the animal. Experiences (percepts, thoughts, feelings, memories) are active products of the organism and are structuralized in accordance with the structure of the experiencing animal. The philosophical conclusions from this ever increasing body of data have not been drawn as yet since this body of data is scattered in studies of the feeble-minded, of abnormal psychology, neuro-psychiatry, animal psychology, ethno-psychology, child psychology, anthropology, etc. Heinz Werner is the first to attempt a systematization of these data. The work in which he attempted to give us a synopsis of these data is scholarly, reliable, and meticulous. While the last German edition of his work was somewhat interpretive, the present American edition appears to the reviewer somewhat to lean in the opposite direction—it is all too

factual, avoiding interpretations whenever possible. The opinions concerning this method of presentation will probably be divided, and the majority of the readers will no doubt hail the factual seriousness of the book. All will probably agree, however, that it is a pioneer work of admirable maturity.

When replacing philosophical speculation concerning the nature of human knowledge by the results of psychological observation and experiment, developmental psychology revolutionizes epistemology which, in turn, is the basis of the methodology of any science. Heinz Werner's book is to be regarded as a distinguished contribution in this direction. Although not directly concerned in this book with these general problems he has nevertheless organized his material with a fine scientific sense so as to shed light on the development of the concepts underlying scientific endeavor, namely on space, time, and causality, as they exist on different developmental levels and levels of pathological primitivization. It was the spirit of the XXth century that impressed upon science a relativistic character as reflected in relativistic physics, Freudian psycho-dynamics and Marxian economics. As in modern physics, space and time are subject to the principle of relativity, so do they become in modern psychology, as the material collected by Heinz Werner amply demonstrates that their nature is dependent on the developmental level of the living organism by whose experience time, space, and causality are created. This relativistic tendency expressed by the Gestalt psychological and organismic teachings which maintained the interdependence of organism and environment as well as the interdependence of function and total organism, gains a fuller expression in the discoveries of developmental psychology. Functions hitherto mostly regarded as objective reflections of the outside world or as unique to the human mind, appear relativised in the light of the discoveries of developmental psychology which unearthed the corresponding functions of other developmental levels of living organisms. In this light, Heinz Werner's contribution gains specific significance.

All through the presentation of this unusual wealth of data, Werner remains true to the organismic point of view. Functions are explained in terms of the total organism to which they belong; characteristics of a function are considered as its aspects; and attempts at piecemeal description of these characteristics as elements forming a function are being systematically discouraged. Though

this method of thinking is a typically dynamic one, Werner's main concern remains the structure of the different functions on different developmental levels. Similar to Goldstein and the Gestalt psychologists, with the possible exception of Lewin, his main concern is so prevalently determined by the aim to build a dynamic morphology of perceiving, thinking, and acting, that the emotional dynamics of the personality are all but disregarded. Werner shows us the levels of structuralization of the different functions. We learn from him that there is a meaningful lawfulness and even a dynamic lawfulness implied in the structuralization of these functional levels. He shows us that the different functional levels are not possessed exclusively by a group of living creatures but that even in the civilized human being of our times, the different lower functional levels are coexistent with the highest ones. He shows us that the lower functional levels cannot be considered immediate historical predecessors, of the higher levels, though they may be analogous to these predecessors. However, we hear from him nothing about the relation of these different structural levels to the development of the dynamics of the personality as discovered by psychiatric and especially psycho-analytic investigations. The organism is considered as a whole, the functions are dealt with as an aspect of the life of the organism. Even the problem of personality organization is dealt with, but no developmental theory of personality dynamics is touched upon. Neither the text nor the index has reference to psycho-sexual development, to the unconscious, to the work of Freud. This is perhaps the only gross lack of this unusually rich, well rounded and broadminded presentation. This lack, however, is not merely a formal one. It has bearing on the present state of developmental psychology as well as on the nature of organismic psychology in general. Organismic psychology is an important step towards the integration into a meaningful whole of the functions which were earlier considered isolated entities. It is in many respects a successful attempt. It remains, however, shy of having a personality theory that could account for the development of the dynamics of personality of which the developmental levels of functional structures are only expressions. Neither organismic psychology nor the even younger organismic developmental psychology has arrived at a personality theory. Viewed from this angle, this important lack of Heinz Werner's presentation is perhaps a merit rather than an

omission. He reflected truly the state of the science the results of which have been first systematized by him. An attempt at integrating it with personality theory would not have been in keeping with the true state of affairs. Neither organismic psychology in general, organismic developmental psychology in particular, has arrived at a personality theory, nor has psychiatric and psycho-analytic research been able to instigate such research and to develop a theory that would explain the dependence upon developmental levels of personality dynamics of the developmental levels of perceptual, motor, thought, and action structures. Werner has nevertheless integrated a body of data without the systematization of which fruitful progress could probably not be expected on either side. It is to be hoped that Werner's presentation will be a powerful stimulation for both sides to reach a common point of understanding through factual investigations, or through interpretation of already secured data.

In the last few years clinical psychology has developed methods of investigating and diagnosing personality. Examples of these methods, called "projective techniques" are the Rorschach, the Szondi, the Thematic Apperception, etc. Tests, play, drawing, clay modelling, etc., techniques. The concept-formation tests have similar features and the intelligence tests, when evaluated qualitatively, have some kindred implications. These means, evolved on the basis of empirical findings have been recently used to study human development. Their usefulness in developmental investigations—even as crude empirical tools—is a well-nigh established fact. The theoretical unification of the empirical findings has, however, not been attempted as yet. The material Werner has systematized sheds light in many respects upon the empirical data obtained with these techniques. The clinical psychologist and the student of human development using these "techniques" will gain appreciable help by viewing his material in light of the knowledge offered by Heinz Werner's book. As L. K. Frank put it, projective techniques open a path into the "private world" of the individual—whether healthy or afflicted. It is in the study of this private world in which rudiments of earlier developmental levels survive and become discoverable, that the knowledge gathered and systematized by Werner may achieve great practical importance. To clinicians and investigators of development this book should prove to be inspiring.

Werner shows us that the nature of perceptions, concepts, mode

of thinking, etc., varies qualitatively on different developmental levels. He writes: "It is one of the most important tasks of developmental psychology to show that the advanced form of thinking characteristic of western civilization is only one form among many, and that more primitive forms are not so much lacking in logic as based on logic of a different kind . . . neither illogical nor prelogical. It is simply logical in another, self-contained sense" (p. 15-16). *Perception* on lower developmental levels is shown to be "physiognomic," animistic, the meaning of the percepts being received as a subjective impression rather than an objective cognition. *Space* is being subjectively created around the human body and its natural directions and organized as a localization of action. *Time* conception is created by natural happening and human action and thus is incontinuous, concretistic, having frequently a purely egocentric character. *Causality* is conceived as creation by action of the causal conditions. *Thinking* on lower developmental levels is shown to be diffuse and concretistic at the same time with concepts varying between qualitative configurational, concrete individual, and concrete-schematic abstractions. Perception on primitive levels is affect-ruled; thinking and causality are magical. Whether the emotional experience on these levels differs from ours remains an open question. The author's silence concerning this point makes it probable that no such difference is assumed. The great problem not yet solved and hardly even clearly stated in developmental psychology is just how these affects and emotions which rule the primitive physiognomic perception, create the first concepts of space, time, and causality, and constitute the essence of magical thinking, assume the rôle they play in the civilized human being of the western world. The crystallization of "objective" space, time and logic, the receding of the affective realm to positions relatively remote from the objective realms, as well as the eventual interaction of the two, are the great problems of developmental psychology. For an attack on these problems the systematizing work of Heinz Werner will prove an indispensable preparation. It is, however, probable that the methods and discoveries of psychoanalytic research, which already have given us some insight into the interaction of reality and primitive animistic thinking ruled by wishes or affects, will likewise prove indispensable.

Psychology has a long history; the science of psychology, however, is very young. If psychology be the science striving to discover the

laws of human behavior, developmental psychology is not one of its branches but its main stem. Scientific understanding is genetic understanding and genetic understanding is the discovery of the laws of development. Discoveries from the different fields of psychological observation converge into a picture of development. In those which do not yet do so (eg., many discoveries in the field of perception), developmental studies will follow and reveal much about the nature of these perceptual phenomena.

Heinz Werner's truly compendious work is a first attempt to show that the different fields of psychology become really integrated only when viewed from the developmental point of view. The careful reader will be confronted with a multiplicity of problems to be solved and with points where an experimental decision is indispensable, easily possible, but not yet made. Werner's book is an inspiring invitation to a vast field of manifold experimental possibilities.

The Menninger Clinic
Topeka, Kansas

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(There will always be two pages of book titles, listed in the order of receipt, i.e., the most recently received books will be found at the end of the list.)

PHILLIPS, D. E. The Human Element in Literature. New York: Fortuny, 1940. Pp. 230.

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